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Ecosystem services and tradeoffs in the home food gardens of African American, Chinese-origin and Mexican-origin households in Chicago, IL

John R. Taylor[1]*, Sarah Taylor Lovell[2], Sam E. Wortman[2] and Michelle Chan[3]

[1]Falk School of Sustainability, Chatham University, Pittsburgh, PA, USA.
[2]Department of Crop Sciences, University of Illinois Urbana-Champaign, Urbana, IL, USA.
[3]College of Applied Health Sciences, University of Illinois Urbana-Champaign, Urbana, IL, USA.
*Corresponding author: jrtaylor@chatham.edu

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Abstract

With increasing urbanization and environmental degradation, urban landscapes are increasingly expected to provide a wide range of ecosystem services typically associated with rural areas, including biodiversity conservation and food production. Because residential landscapes constitute the largest single urban land use, domestic gardens have emerged as a topic of research interest and planning concern. The ecosystem services (or disservices) these landscapes provide, however, have not been rigorously measured, nor have tradeoffs between the services they provide been assessed. In this study, semi-structured interviews were conducted with 59 African American, Chinese-origin or Mexican-origin households with on-lot or vacant lot food gardens in Chicago. Crop plants and cultivated ornamental plants on the lot were inventoried and mapped at the species level. A total of 123 edible plant taxa from 25 families and 288 ornamental plant species from 85 families were identified, for a combined total of 387 species from 90 families. Cumulatively, the gardens of African American households were relatively rich in ornamental plant species and families, while those of Chinese-origin households had a depauperate flora. Crop plant richness was more even across sample types. Shade trees and a developed shrub layer were absent from most gardens, possibly representing a tradeoff in ecosystem services in favor of food production. The richness of the aggregate 2.1 ha of residential property inventoried in this study was comparable with or exceeded that of a 34 ha prairie remnant west of Chicago. However, only 35 (9.6%) of the inventoried species were native to the Chicago area.

Key words: biodiversity, agrobiodiversity, ecosystem services, green infrastructure, home gardens, urban agriculture, food security, migrant gardeners

Introduction

With increasing urbanization and environmental degradation, urban landscapes are increasingly expected to provide a wide range of ecosystem services typically associated with rural areas, including biodiversity conservation, water filtration and stormwater infiltration, food production and even carbon sequestration for climate change mitigation. At the same time, these landscapes must continue to fill their cultural roles in affording, for example, recreational opportunities (Lovell and Taylor, 2013). Because residential landscapes constitute the largest single land use category in many urban areas, domestic gardens have emerged as a topic of research interest and planning concern (Cameron et al., 2012; Dewaelheyns et al., 2014). While these gardens have been shown to fulfill important functions such as conserving biodiversity (Smith et al., 2006; Loram et al., 2008) and promoting human well-being (Matsuoka and Kaplan, 2008), their contributions to the broader urban green infrastructure have not been rigorously measured (Cameron et al., 2012). (We broadly define green infrastructure as any landscape feature providing ecosystem services (Lovell and Taylor, 2013).) In fact, in the developed world, research on the contributions of domestic gardens to even plant diversity has mostly focused on European cities—with limited studies in US cities—possibly due to the assumptions that these spaces are dominated by lawn and are difficult to access because they are privately owned (Taylor and Lovell, 2014). Studies in the USA have further tended to use neighborhood rather than household level variables to examine the relationship between sociodemographic characteristics and plant diversity (cf. Kinzig et al., 2005).

In studies of European cities, gardens—whether private home gardens or community or allotment gardens in public spaces—have been characterized as contributing strongly to the plant diversity of the urban environment, with largely non-native species accumulating across gardens at a higher rate than for other urban land use types due to the internal heterogeneity of gardens and the management practices of gardeners (Loram et al., 2008). Plant diversity is key to maintaining the overall species diversity of urban environments, because it functions as the template for biodiversity at higher trophic levels and is the only component of urban biodiversity over which humans have direct control (Faeth et al., 2011). However, with few exceptions (cf. Smith et al., 2006; Loram et al., 2008; Knapp et al., 2012; Van Heezik et al., 2014), plant diversity surveys and inventories of residential gardens in the USA and elsewhere in the developed world have focused on spaces that are visually accessible to researchers (Cook et al., 2012), primarily front yards and parkways (the strip of land between sidewalk and street) (Hunter and Brown, 2012). Homeowners' landscape preferences, however, may differ between front and back yards, with potential implications for landscape structure and biodiversity (Cook et al., 2012). While the composition of the front yard purportedly reflects social class, backyards are alleged to be 'dreamscapes' reflecting the owner's 'true' landscape preferences (Larsen and Harlan, 2006). The form of these landscapes is reportedly independent of factors such as household income (Larsen and Harlan, 2006) that drive diversity (Hope et al., 2003), but the culture and social class of household members can be expected to influence backyard landscape aesthetics. The forms of urban backyards, which are often visible from public ways and adjacent houses (Taylor and Lovell, 2015) may also be influenced by neighborhood landscape norms.

Research on residential plant diversity in developed countries has further tended to focus on lower density residential developments in suburban areas (cf. Daniels and Kirkpatrick, 2006; Van Heezik et al., 2014) and on owner-occupied and/or single-family dwellings (cf. Smith et al., 2006; Loram et al., 2008; Van Heezik et al., 2014), even though cultivated plant richness has been found to increase with housing density, up to a point (Loram et al., 2008; Marco et al., 2008). The majority of urban residents live in multifamily buildings, and the scant existing research suggests that the diversity and dynamics of their shared, sometimes co-managed yards differ from those of yards managed by a single, home-owning household (Loram et al., 2008).

In the USA, residents of the urban core are also more likely to live in poverty than those who live in metropolitan areas but not in principal cities (Denavas-Walt and Proctor, 2014). While the biodiversity and ecosystem processes of vacant lots in urban low-income neighborhoods have been characterized and compared with those of community gardens (Grewal et al., 2011; Yadav et al., 2012), the species composition and social-ecological dynamics of surrounding private gardens have been overlooked. The strategies that households in these neighborhoods use to furnish their backyard 'dreamscapes' with plants may be much different from those of households with greater financial resources. In the USA, factors other than household income, such as social capital, social connectedness and lifestyle may contribute to plant diversity at the level of the residential lot (Grove et al., 2006; Taylor and Lovell, 2014; Taylor and Lovell, 2015).

In addition to conserving biodiversity, multifunctional urban landscapes are increasingly expected to provide food (Lovell, 2010). Published research on the biodiversity of urban food gardens in the USA has focused on the crop diversity (Corlett et al., 2003; Vitiello and Nairn, 2009) or overall plant diversity of community gardens (Clarke and Jenerette, 2015), with a single study documenting the crop diversity of home gardens (Airriess and Clawson, 1994). No studies in the USA, to our knowledge, have systematically examined the overall plant diversity, structure (two- and three-dimensional spatial organization), or ecosystem processes of urban residential gardens in the context of food gardening. Food gardening may have a large impact on residential landscape structure, particularly in backyard spaces, and on biodiversity, with food plants displacing native or non-native ornamental plants, lawn, and tall, woody vegetation that casts shade. Unlike the perennial plants they replace, many food plants are short-lived annuals, providing only ephemeral habitat for vertebrates and invertebrates.

The literature on home gardens in developed and developing countries suggests a wide range of factors may influence crop plant diversity in these domestic agroecosystems (Taylor and Lovell, 2014). In developing countries, food production as an ecosystem service may be concentrated in lower income urban households, leading to higher edible plant richness in the associated gardens (Jaganmohan et al., 2012; Cilliers et al., 2013). In the USA, on the other hand, urban food production—and presumably food plant richness—is reportedly correlated with household income and home ownership (Smith et al., 2013). In the rural North, women's gardens have been reported to harbor greater crop plant diversity than men's gardens (Reyes-García et al., 2010). The traditional foodways of internal or international migrants may drive the species composition of gardens (Airriess and Clawson, 1994; Corlett et al., 2003; Nazarea, 2005; Galluzzi et al., 2010; Mazumdar, 2012) as may a lack of access to culturally appropriate foods (Kortright and Wakefield, 2011). Increasing transnationalism potentially facilitates the bidirectional flow of germplasm across borders (Aguilar-Stoen et al., 2009), and the urban home gardens of migrants in developed countries may consequently harbor traditional crop species and varieties (Gladis and Pistrick, 2011; Taylor and Lovell, 2015), as do their rural counterparts in both the North and South (Nazarea, 1998; Nazarea, 2005; Aguilar-Stoen et al., 2009; Galluzzi et al., 2010). In the rural south, gardens afford opportunities for farming households to experiment with and to modify new varieties with little risk to household income (Aguilar-Stoen et al., 2009). Urban gardeners in the north may similarly experiment with new varieties and crops, enriching the species composition of residential lots (Taylor and Lovell, 2014).

This multidisciplinary study, which was part of a multi-scalar project focusing on the social and ecological dynamics of urban food production in Chicago, seeks to address these gaps in the literature by: (1) documenting the plant diversity of the home food gardens of inner city ethnic and migrant households residing in single- and multifamily dwellings; (2) examining the factors, processes and practices influencing the cultivated plant diversity of those gardens; and (3) developing a foundation for future quantitative research on residential lots with food gardens and their contributions to urban green infrastructure.

Preliminary results from this project, based on an initial sample of 31 home food gardens, were previously published as a From the Field report in Renewable Agriculture and Food Systems (Taylor and Lovell, 2015). This paper reports the results for a final sample of 61 gardens. Based on data from this larger sample, it updates previously reported summary variables and explores in further detail the cultivated plant diversity of these gardens, the factors contributing to that diversity, the three-dimensional structure of the gardens and the potential tradeoffs between ecosystem services in the space of the home garden.

Methods

Study site and focal groups

The project focused on home gardening among three groups—African American, Chinese-origin and Mexican-origin households—in Chicago, IL. For purposes of this study, a home food garden is defined as a fruit and/or vegetable garden on leased, owned or borrowed land adjacent to the gardener's residence (Kortright and Wakefield, 2011). The first two groups were selected based on findings from previous research on the spatial distribution of food gardens in Chicago. Single-plot vacant lot gardening, a form of home gardening, is most common in disinvested, predominantly African American neighborhoods on the city's south and west sides, while Chinese-origin households appear to participate in on-lot food gardening at much higher rates than other groups (Taylor and Lovell, 2012). Mexican-origin households were included because of their potential policy relevance. Persons of Mexican descent constitute the largest Latino group in Chicago, and the city has the second largest Mexican immigrant population of any US city (Zong and Batalova, 2014). For Chicago NGOs such as the Little Village Environmental Justice Organization, urban agriculture has been one strategy for enhancing community development and food security in the city's majority Mexican-origin neighborhoods. The inclusion of Mexican-origin households in this study further provides an opportunity to compare the garden-related practices of two different immigrant groups.

With a land area of more than 606 km^2, Chicago is the third most populous city in the USA. As with many industrial cities in the USA, the city's population has declined since the middle of the 20th century, from a high of over 3.6 million in 1950 to 2.7 million in 2010. Population loss, disinvestment and economic redevelopment have been highly uneven, spatially and socially. Predominantly African American community areas on the city's south and west sides have suffered the highest rates of population loss. The population of Englewood on the south side, for example, declined from a peak of more than 97,000 inhabitants to approximately 40,000 in 2000 (Stockwell, 2005) and lost an additional 10,000 residents from 2000 to 2010 (City of Chicago, 2015). Downtown Chicago, on the other hand, has recently experienced a population and housing boom, with the population almost doubling between 2000 and 2010 (Levy et al., 2012).

In 2012, the project initially focused on three study areas that were predominantly African American, Chinese-origin or Mexican-origin. By 2014, the scope of the project had expanded to include 13 community areas on the city's south and west sides. African American households were selected from seven predominantly African American community areas on the south side. Mexican-origin households were selected from a majority Mexican-origin community area on the south side and another on the west side. Chinese-origin households were selected from Armour Square, which includes Chicago's Chinatown, and four additional community areas on the near west and near south sides with minority Chinese-origin populations. (With the exception of Armour Square, the specific community areas are not identified to protect the confidentiality of study participants. For similar reasons, participants are identified by pseudonyms throughout this paper.) The community areas from which Chinese- and Mexican-origin households were drawn overlapped.

Because so little research has been conducted on home food gardens in US cities, a purposive sampling strategy was employed to explore the social and ecological dynamics of home gardens across a small but diverse sample of households. Households with gardens in the selected areas were initially identified from the primary and secondary authors' dataset of larger home gardens in Chicago. This dataset was developed through manual photointerpretation of aerial images in Google Earth (Taylor and Lovell, 2012). Flyers in English, Spanish and Chinese were mailed to these households, and gardeners were asked to contact a study representative (the primary author or a bilingual research assistant) about participating in the study. Project staff visited non-responding households in person. Additional, smaller food gardens were identified through fieldwork—by driving and walking up and down neighborhood streets and alleys—and were added to the recruitment effort. Households were also recruited through the personal contacts of the undergraduate and graduate student research assistants who interviewed Mexican- and Chinese-origin gardeners. The research assistants were 'insiders' who lived in the neighborhoods from which gardeners were recruited, facilitating both gardener recruitment and data collection. The Chinese-origin research assistants spoke Cantonese and Taishanese, a dialect related to Cantonese, as did the households recruited for the study. Gardens of diverse types and sizes and households of diverse structure were sought during recruitment.

Data collection

In the 2012 and 2014 growing seasons, data collection began with a visit to each participating household. During this visit, project staff conducted the first of one to three in-depth, hour-long interviews with the household's primary gardener on a wide range of topics, including garden history, gardening practices and personal history. The questions asked during the interview were developed with reference to Vogl et al. (2004), Nazarea (1998), Martin (2004), and literature on tropical homegardens (cf. Méndez et al., 2001; Nair, 2006; Aguilar-Stoen et al., 2009; Buchmann, 2009). Interviews often began in the garden, which allowed the interviewer to observe the gardener's practices and his or her interactions with both plants and passersby. The primary author conducted all interviews with African American gardeners, while bilingual research assistants conducted interviews with Chinese- and Mexican-origin gardeners.

Food gardens were inventoried and surveyed. Crops were classified at the species level with several exceptions. Crops in the genus *Brassica*, for example, exhibit a wide range of functional diversity within species—e.g., cabbage, collards and kale, all varieties of *Brassica oleracea*—and were consequently assigned to functional taxa within species, to reflect the importance of their cultural uses. Similarly, the species *Capsicum annuum* is represented by two functional taxa, hot pepper and sweet pepper, and was recorded as such. Culinary herbs were classified as food crops, while the few exclusively medicinal herbs inventoried—including rue (*Ruta graveolens*) and marijuana (*Cannabis sativa*)—were classified as ornamental species because of their small number. (Gardeners, particularly Chinese-origin gardeners, reported that they grew some food crops such as bitter melon (*Momordica charantia*) and Jerusalem artichoke (*Helianthus tuberosus*) for both their culinary and medicinal qualities.) The vast majority of cultivated plants were identified in the field by the primary author, who supervised plant surveys and garden mapping to ensure consistency in the application of methods across gardens. Plants that could not be identified in the field were photographed in detail, to assist in identification in the laboratory.

In ecological research, plant abundance is commonly measured as plant number or cover (Wheater et al., 2011). However, counting individual plants in gardens is time consuming (Vogl et al., 2004), and plant cover has been used as a measure of abundance in studies of both home gardens and community garden plots (cf. Clarke and Jenerette, 2015). Because abundance in this study was used as a proxy for crop importance, it was measured as the area devoted to the production of each crop (henceforth referred to as 'crop production area') rather than as plant number or plant cover in the strict sense of foliar cover as measured by the vertical projection of foliar area to the ground surface (Anderson, 1986). Measurement was complicated by gardeners' diverse planting systems, including polycultures (the mixed cultivation of two or more crop species) and the maximization of production area by some gardeners through the use of garden structures such as fences, arbors and trellises (see Figure 1). Consequently, to standardize the measurement of plant abundance across crops and gardens, production area was measured for each crop independently—allowing for the vertical overlap of crops—according to a set of decision rules developed by the primary author (Table 1).

All cultivated ornamental plant taxa on the lot(s) associated with the participating household were inventoried at the species level when possible. Following Smith et al. (2006), no attempt was made to identify individual, naturally occurring varieties or cultivated varieties (cultivars). Horticultural cultivars of complex, often interspecific heritage were placed in a single taxon at the genus level, e.g., *Rosa* cv. Abundance data were not collected for individual ornamental plant species. Instead, the cultivated area of all ornamental plants on the lot, excluding trees and lawn, was measured using the same rules as for crop plants.

Based on the inventory and survey data collected in the field, summary variables were calculated for each garden (Table 4), and lot size was determined from county property records (Table 3). Summary variables were compared across the three groups of gardeners by GLM procedure in SAS 9.4 with LSMEANS for mean separations using the Tukey–Kramer adjustment (adjust = Tukey) (Table 2). Data were log transformed prior to analysis to improve normality. Back transformed values for means and confidence intervals are reported in the text, tables and figures (McDonald, 2009). Because of back

Figure 1. Expansion of production area in the food gardens of Chinese-origin households in Chicago, IL, through the use of horizontal and vertical supports for crop plants. (1) An arbor supporting a canopy of winter melon (*B. hispida*) over a ground layer of shade-tolerant leafy crops. (2) A property line fence supporting a red-podded variety of yardlong bean (*Vigna unguiculata* subsp. *sesquipedalis*).

Table 1. Decision rules for calculating the production area of each crop grown in 61 home food gardens of African American, Mexican-origin and Chinese-origin households in Chicago, IL.

1	The production area of each crop, including spatially overlapping or layered crops, was calculated independently
2	When crops were planted in beds of a single crop, production area was recorded as the area of the bed excluding paths
3	When crops were planted in beds in polyculture (as mixtures), the percent cover of each crop was estimated and was used to calculate crop production area. For example, if sweet potato (*Ipomoea batatas*) was estimated to cover 10% of a 10 m^2 bed containing a mixture of crops, the production area for sweet potato was calculated to be 1 m^2
4	When crops were planted in rows, production area was calculated based on the width and length of the row, including one half of the distance between the row of interest and adjacent rows
5	When crops were grown in pots, production area equaled the surface area of the pot
6	Fruit tree cover was calculated from the diameter of the canopy
7	When structures, e.g., arbors, trellises or fences, were used to support vining crops, production area was calculated based on the dimensions of the structure. The areas of each vertical or horizontal surface covered by the structure crop were summed. Based on this method, the area for a 3-m-long row of yardlong beans (*Vigna unguiculata* subsp. *sesquipedalis*) planted at the base of a 2-m-high vertical trellis, for example, would be 6 m^2. When a single structure supported more than one crop species, the contribution of each crop to the total area of the structure was estimated

transformation, confidence intervals are not symmetric around means.

To compare crop plant composition across gardens, a non-metric dimensional scaling (NMDS) ordination of gardens was performed using a Bray–Curtis dissimilarity matrix of relative abundance data for crop taxa (R 3.1.3) (McCune et al., 2002). To test associations between crop and ornamental plant richness and species density and lot and garden characteristics, Pearson's product moment correlations and linear regressions were conducted for the sample as a whole and by ethnic group (R 3.1.3). Because some gardens were inventoried and surveyed multiple times during the project and others only once, plant inventory and survey data from only a single comparable point in time, in mid to late summer, rather than cumulative data, were included in these analyses.

Using an emergent coding approach, in which themes were allowed to emerge from repeated readings (Patton, 2014), interview transcripts were coded by hand or with NVivo for Mac. Analytic concepts were developed from the initial codes and were documented in concept memoranda (Patton, 2014). Sociodemographic data for gardeners and qualitative and quantitative data for gardens, e.g., species inventories and garden surveys, were kept in separate Excel workbooks linked to interview data by codes for gardeners. All study procedures, instruments and forms were reviewed and approved by the university's Institutional Review Board.

Table 2. Comparisons of summary variables for 61 home food gardens of American, Mexican-origin and Chinese-origin households in Chicago, IL.

	African American sample	Chinese-origin sample	Mexican-origin sample
Food crops			
Cultivated ground area			
Mean (m^2)	17.51a	23.24a	12.16a
95% confidence interval	10.19–30.10	16.99–31.80	6.69–22.12
Ratio of cultivated ground area to lot area			
Mean	0.042b	0.111a	0.036b
95% confidence interval	0.023–0.079	0.081–0.151	0.019–0.065
Total crop production area (w/o fruit tree cover)			
Mean (m^2)	21.12b	44.06a	17.93b
95% confidence interval	12.27–36.38	32.97–58.87	10.47–30.70
Total crop production area plus fruit tree cover			
Mean (m^2)	22.43a	45.79a	25.62a
95% confidence interval	12.77–39.38	34.58–60.64	14.66–44.76
Ratio of total crop production area plus fruit tree cover to lot area			
Mean	0.054b	0.218a	0.075b
95% confidence interval	0.029–0.102	0.159–0.300	0.044–0.128
Crop richness			
Mean (taxa $garden^{-1}$)	11.79a	12.31a	7.35b
95% confidence interval	8.77–15.85	10.26–14.76	5.96–9.08
Density of crop taxa			
Mean (taxa m^{-2} $garden^{-1}$)	0.68a	0.53a	0.60a
95% confidence interval	0.43–1.08	0.38–0.72	0.36–1.03
Ornamental plants			
Ornamental plant area			
Mean (m^2)	3.93a	0.45b	3.88a
95% confidence interval	1.09–13.62	0.14–1.14	1.61–9.17
Ornamental plant richness			
Mean (taxa $garden^{-1}$)	10.90a	2.18b	9.87a
95% confidence interval	4.83–23.29	1.21–3.57	5.69–16.65

Means and confidence intervals have been back transformed from the log transformed values.
Confidence intervals are not symmetric around the mean due to back transformation.
Means followed by different letters are considered significantly different at $P < 0.05$.

Results

Gardener characteristics

Updated sociodemographic characteristics for the 59 gardeners (19 Mexican-origin, 23 Chinese-origin and 17 African American) in the final study sample are provided in Table 3. (Note that two gardeners—one African American and one Chinese-origin gardener—each cultivated two spatially distinct gardens, for a total of 61 gardens.) In summary, more African American gardeners were homeowners (16 of 17) than members of the other two groups, and African American gardeners and Chinese-origin gardeners were, as a whole, older than Mexican-origin gardeners, more of whom had young children at home. All Mexican- and Chinese-origin gardeners were immigrants, and 7 of the 17 African American gardeners had migrated to Chicago from the American South as teenagers or young adults. Approximately 90% of Chinese-origin gardeners participating in the study were women, while over one-third of Mexican-origin and African American gardeners were men.

Garden typologies, features and land use areas

As with the preliminary sample of 31 gardens (Taylor and Lovell, 2015), garden location and spatial organization for the final sample of 61 gardens were highly diverse, with common patterns within each group of gardens (Table 3). Both backyard ($n = 12$) and single-plot vacant lot food gardens ($n = 6$) of African American households generally had an orthogonal design, with food crops planted separately from ornamental plants in rows or beds in native soil, often at the back of the lot adjacent to the alley. There were exceptions. One gardener grew her crops entirely in pots, and two gardeners used raised beds filled with a topsoil–compost mix because of concerns about soil contamination. Two other gardeners

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Table 3. Sample characteristics of the gardeners and gardens selected for a study of 59 African American, Mexican-origin and Chinese-origin households with home food gardens in Chicago, IL (updated from Taylor and Lovell, 2015).

	African American sample	Chinese-origin sample	Mexican-origin sample
Gardener characteristics			
Sample size	17	23	19
Gender ratio			
Male (%)	35.3	9.5	36.8
Female (%)	64.7	90.5	63.2
Age range	Late 40s to late 80s	Late 40s to early 80s	Early 30s to mid-80s
Foreign born (%)	5.9	100	100
Household income <2 × poverty level (%)	42.9	53.8	63.2
Garden characteristics			
Sample size	18	24	19
Location			
Single family lot (%)	55.6	66.7	5.3
Multifamily lot (%)	11.1	33.3	68.4
Vacant lot (%)	33.3	0	26.3
Lot size			
Mean (m^2)	452.9	236.1	360.1
Range (m^2)	275.2–1153.9	51.6–414.7	261.2–871.0

Table 4. Summary variables calculated for a study of 61 home food gardens of African American, Mexican-origin and Chinese-origin households in Chicago, IL.

1. Individual crop production area
2. Total crop production area (for all food crops except fruit trees, including vertical and layered areas)
3. Total cultivated ground area of all food crops except fruit trees (the ground area of the garden used for food production, excluding paths)
4. Fruit tree cover
5. Total ornamental plant area
6. Crop richness (the total number of food crop taxa)
7. Density of crop taxa (food crop richness/total cultivated ground area of all food crops)
8. Ornamental plant richness (the total number of ornamental plant species on the lot)

planted polycultures of ornamental and food plants. Garden sharing was not uncommon. One backyard gardener also gardened a neighbor's vacant lot, two gardeners reported sharing space in their gardens with neighbors or friends, and another backyard gardener helped tend a friend's garden on the vacant lot adjacent to the former's residence.

Single-plot vacant lot gardens ($n = 5$) were also commonly associated with Mexican-origin households, but the majority of gardeners grew their crops on the lots of the multifamily buildings in which they lived (and which they sometimes owned). Growing food in shared spaces or under conditions of tenancy influenced garden structure (Taylor and Lovell, 2015). One gardener grew vegetables primarily in pots because, as a tenant, she was not allowed to plant in the ground, while three other tenant gardeners colonized unused front yards with food plants. On-lot gardens in the final sample were often pushed to the edges of the backyard, leaving a central rectangle of lawn or paving for shared recreational use (Taylor and Lovell, 2015).

Occasionally used to support vining crops in African American and Mexican-origin households' gardens, trellises, arbors and fences were a defining feature of those of Chinese-origin households (Taylor and Lovell, 2015). The degree and form of vertical gardening in these gardens varied greatly (Fig. 1). At one end of the spectrum, gardeners grew crops such as winter melon (*Benincasa hispida*), fuzzy melon (*B. hispida* var. *chieh-qua*), bitter melon, yardlong bean and squash or pumpkin (*Cucurbita* sp.) on pre-existing fences 1–2 m in height along property lines, on internal trellises or on small, relatively low arbors built from found or purchased lumber. In the extreme, they constructed permanent arbors over 2 m in height that covered the entire growing area. Successional leafy crops, e.g., *bok choy* (*Brassica rapa* subsp. *chinensis*), requiring less light than root or fruiting crops were grown beneath these structures, sometimes doubling the production area (Taylor and Lovell, 2015).

The gardens of Chinese-origin households were located primarily in the backyards of single-family dwellings, multifamily buildings or family buildings (multifamily

Table 5. Plant families with the ten highest levels of representation in the combined food crop taxa of 61 home gardens in Chicago, by group.

African American		Chinese-origin		Mexican-origin	
Family	**% of taxa**	**Family**	**% of taxa**	**Family**	**% of taxa**
Brassicaceae	17.2	Brassicaceae	15.5	Solanaceae	20.4
Lamiaceae	14.1	Cucurbitaceae	15.5	Lamiaceae	16.3
Cucurbitaceae	9.4	Solanaceae	10.3	Rosaceae	14.3
Rosaceae	9.4	Lamiaceae	8.6	Poaceae	10.2
Solanaceae	9.4	Rosaceae	8.6	Brassicaceae	8.2
Amaryllidaceae	6.3	Amaryllidaceae	6.9	Cucurbitaceae	8.2
Apiaceae	6.3	Fabaceae	5.2	Asteraceae	6.1
Fabaceae	6.3	Amaranthaceae	6.9	Adoxaceae	2.0
Amaranthaceae	4.7	Asteraceae Basellaceae Convovulaceae	3.4	Amaranthaceae	2.0
Asteraceae	3.1			Amaryllidaceae Ericaceae Fabaceae Piperaceae Rutaceae Vitaceae	2.0

buildings in which different units are occupied by members of the same extended family) with secondary growing areas in front and side yards. One gardener cultivated her own backyard and that of her next-door neighbor. Three other gardeners who lived in townhouse developments gardened their small front yard gardens and also appropriated common space for food production. Lawn was entirely absent from all of the gardens of Chinese-origin households. Gardens were unpaved and almost entirely devoted to food production or combined unpaved growing areas with expanses of paving. Production was sometimes expanded to paved areas by planting crops in recycled containers, including bins, tubs and buckets.

Mean total cultivated crop area was not significantly different across groups (Table 2), but, on average, Chinese-origin households devoted a significantly higher proportion of their lot to food production than did African American or Mexican-origin households, which did not significantly differ (0.111 versus 0.042 and 0.036, respectively, $P < 0.05$; Table 2). Mean total crop production area—not including fruit tree cover—of the gardens of Chinese-origin households was significantly greater than that of either African American or Mexican-origin households' gardens, which were not significantly different (44.06 m^2 versus 21.12 m^2 and 17.93 m^2, $P < 0.05$; Table 2).

Fruit tree plantings, a form of domestic agroforestry, may be an additional strategy home gardeners use to maximize space. Fruit trees were most abundant in Mexican-origin households' gardens and least abundant in those of Chinese-origin households. Including fruit tree cover increased average total crop production area of the former by 43% to 25.62 m^2; fruit tree cover contributed 6% and 4% to the total production area of African American and Chinese-origin households' gardens, respectively. With the addition of fruit tree cover, production area was not significantly different across groups ($P > 0.05$; Table 2). However, with vertical layering from both structures and fruit trees, the average ratio of production area to lot area increased to 0.218 for the gardens of Chinese-origin households, which was significantly higher ($P < 0.05$) than the ratio for African American or Mexican-origin households' gardens, which did not significantly differ (0.054 versus 0.075, $P > 0.05$; Table 2).

The area occupied by ornamental plants (not including trees) in Chinese-origin households' gardens was on average significantly less than that of either African American or Mexican-origin households' gardens (0.45 m^2 versus 3.93 and 3.88 m^2, respectively, $P < 0.05$; Table 2). Ornamental plant area was not significantly different between the latter two garden types.

Crop plant diversity and culture-specific plant assemblages

A total of 123 edible plant taxa representing 102 species from 25 families were identified across the 61 gardens, including 17 species of fruit crops, 27 species of culinary herbs and 79 taxa of vegetable crops. Only three species, Jerusalem artichoke, pokeweed (*Phytolacca americana*) and fox grape (*Vitis labrusca*) are native to the Chicago area (Swink and Wilhelm, 1994). Across all gardens, the highest numbers of taxa were recorded for the Lamiaceae (14%), Brassicaceae (13.2%), Cucurbitaceae (9.9%), Solanaceae (9.9%) and Rosaceae (7.4%). Gardens of African American households included the greatest number of taxa ($n = 64$) and families ($n = 19$), followed by those of Chinese-origin ($n = 58$ and 16) and Mexican-origin ($n = 49$ and 15) households. Plants from the Brassicaceae made the greatest contribution to the food crop richness of garden tended by African American and Chinese-origin households (17.2 and 15.5%, respectively), while the Solanaceae accounted for 20.4% of the food plant taxa identified in the gardens of Mexican-origin households (Table 5).

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The average crop plant richness of Mexican-origin households' gardens was significantly lower, at 7.35 taxa per garden ($P < 0.05$), than that of African American or Chinese-origin households' gardens. The average richness of the latter two groups of gardens was not significantly different (11.79 versus 12.31 taxa, respectively $P > 0.05$; Table 2). As was found for the preliminary sample (Taylor and Lovell, 2015), density of food crop taxa was not significantly different across the three samples (0.68 versus 0.53 versus 0.60 crops m^{-2}, $P > 0.05$, for African American, Chinese-origin and Mexican-origin households' gardens, respectively; Table 2).

The NMDS plot for all gardens indicates that ethnicity had a strong influence on the crop species composition of all gardens. The gardens of each ethnic group occupy a unique location on axis 1, with some overlap between the gardens of African American and Mexican-origin households on that axis (Fig. 2). On axis 2, the gardens of Mexican-origin households occupy a unique location relative to those of either Chinese-origin or African American households, which occupy a roughly similar location. The gardens of Chinese-origin households are the most tightly clustered in ordination space, indicating that these gardens are the most homogeneous in species composition; those of African American households are the most dispersed, suggesting greater heterogeneity in species composition.

Of the ten taxa with the highest aggregate crop production area for Chinese-origin households' gardens, six—bitter melon, yardlong, winter melon, fuzzy melon, *bok choy* and Chinese spinach (*Amaranthus dubius*)—are unique to those gardens, and only three—green beans and two squash species, *Cucurbita pepo* and *Cucurbita maxima*—are among the ten most abundant taxa in either African American or Mexican-origin households' gardens (Table 6). Four taxa—tomato, cucumber (*Cucumis sativus*), grape and squash (*C. pepo*)—are ranked among the ten taxa with the highest aggregate crop production areas for both African American and Mexican-origin households' gardens. Two highly ranked taxa—collards (*B. oleraceae* Acephala Group) and okra (*Abelmoschus esculentus*)—are unique to the gardens of African American households, while two other taxa—*pápalo* (*Porophyllum ruderale*) and *tomatillo* (*Physalis philadelphica*)—were found only in the gardens of Mexican-origin households. Only *C. pepo* is included among the ten most abundant taxa for all three samples.

Many less abundant taxa were found only in the gardens of a particular ethnic group or were, according to gardeners, connected to ethnic foodways or to foodways of the gardener's place of origin (Taylor and Lovell, 2015) (Table 7). Overall, more unique crop taxa were inventoried in the gardens of African American ($n = 35$) or Chinese-origin ($n = 36$) households than were found in those of Mexican-origin households ($n = 21$). Reporting abundance data at a common level of taxonomic resolution, however, obscures some lower level diversity identified in surveyed

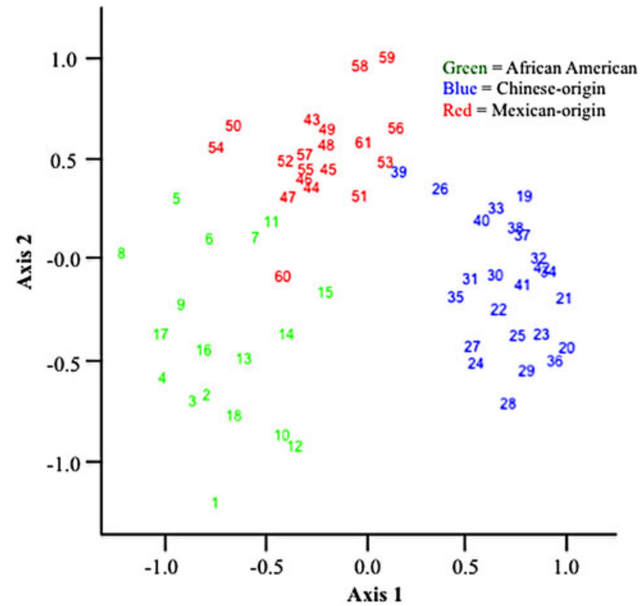

Figure 2. NMDS ordination based on Bray–Curtis dissimilarity matrix for all food crop species (excluding fruiting trees) for 61 home food gardens in Chicago (African American households, 1–18; Chinese-origin, 19–42; Mexican-origin, 43–61).

gardens. For example, a total of 14 hot pepper varieties from three species (*C. annuum, Capsicum chinense* and *Capsicum pubescens*) were inventoried in the gardens of Mexican-origin households in the final sample, an increase of four varieties over the inventory for the preliminary sample (Taylor and Lovell, 2015).

Ornamental plant diversity

A total of 288 cultivated, ornamental plant species from 85 families were identified across the 61 gardens. These include: 114 annuals or tender perennials: 119 hardy, herbaceous perennials: 36 shrub species; 12 tree species: and 7 vining plant species. Only 32 of the inventoried species (11.1%) are native to the Chicago region, according to Swink and Wilhelm (1994). Across all gardens, the highest numbers of species were recorded for the Asteraceae (13.5%), Lamiaceae (5.2%), Asparagaceae (4.5%) and Araceae (3.5%) (Table 8). As a whole, the gardens of African American households included the greatest number of ornamental plant species ($n = 208$) and families ($n = 69$) followed by those of Mexican- ($n = 151$ and 65) and Chinese-origin ($n = 52$ and 28) households. Plants from the Asteraceae made the greatest contribution to the richness of all three garden types, with the relative ranking of other families varying by garden type (Table 8). The ornamental plant richness of African American and Mexican-origin households' gardens was not, on average, significantly different (10.90 species versus 9.87 species per garden, $P > 0.05$; Table 2), while the richness of Chinese-origin households' gardens (2.18 species per garden) was significantly lower ($P < 0.05$) than that of the other two groups' gardens.

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Table 6. Food crop taxa[1] with the ten highest aggregate proportional abundances for 61 home gardens in Chicago, by group.

African American		Chinese-origin		Mexican-origin	
Taxon	**Abund. (%)**	**Taxon**	**Abund. (%)**	**Taxon**	**Abund. (%)**
Tomato (*Solanum lycopersicum*)	20.9	Bitter melon[2] (*M. charantia*)	19.7	*Pápalo*[2] (*P. ruderale*)	19.0
Collards[2] (*B. oleracea* Acephala Group)	12.1	Bean, yardlong[2] (*Vigna unguiculata* subsp. *sesquipedalis*)	14.0	Pepper, hot (*C. annuum*)	12.7
Bean, green or pole (*Phaseolus vulgaris*)	7.3	Bean, green	13.3	Cucumber	11.6
Grape (*V. labrusca*)	7.1	Winter melon[2] (*B. hispida*)	12.4	Tomato	10.8
Cucumber (*C. sativus*)	6.1	Fuzzy gourd[2] (*B. hispida* var. *chieh-qua*)	8.0	Squash (*C. moschata*)	6.8
Pepper, sweet (*C. annuum*)	5.8	*Bok choy*[2] (*B. rapa* subsp. *chinensis*)	3.7	Grape (*V. labrusca*)	6.7
Cabbage (*B. oleracea* Acephala Group)	4.2	Chinese spinach[2] (*A. dubius*)	3.2	Bean, green	6.5
Okra[2] (*A. esculentus*)	3.9	Sweet potato (*Ipomoea batatas*)	2.8	Corn, sweet (*Zea mays* subsp. *mays*)	5.5
Squash (*Cucurbita pepo*)	2.9	Squash (*C. pepo*)	2.1	Tomatillo[2] (*P. philadelphica*)	4.1
Onion (*Allium cepa*), Kale (*B. oleracea* Acephala Group)	2.2	Squash (*C. moschata*)	1.8	Squash (*C. pepo*)	3.9

[1] Does not include fruit trees.
[2] indicates a food crop unique to the sample.

Table 7. Lower abundance food crops associated with ethnic or regional foodways identified in 61 home gardens in Chicago, by group (updated from (Taylor and Lovell, 2015).

African American	Chinese-origin	Mexican-origin
Mustard greens (*Brassica juncea* cvs.)	Garlic chives (*Allium tuberosum*)	*Chipilín* (*C. longirostrata*)
Kale (*B. oleracea* Acephala Group)	Madeira vine (*Anredera cordifolia*)	*Epazote* (*Dysphania ambrosioides*)
Turnip (top and root) (*B. rapa* subsp. *rapa*)	*Kun choy* (*Apium graveolens*)	*Pichueca* (*Jaltomata sp.*)
Sweet potato (root) (*Ipomoea batatas*)	*Saan choy* (*Basella alba*)	*Hierba santa* (*Piper auritum*)
Poke sallet (*P. americana*)	Chinese mustard (*Brassica juncea* cvs.)	*Pipicha* (*P. linaria*)
	Gai lan (*B. oleracea* Alboglabra Group)	Tropical corn (*Zea mays* subsp. *mays*)
	Yu choy sum (*B. rapa* var. *parachinensis*)	
	Mustard spinach (*B. rapa* var. *perviridis*)	
	Tong ho (*Glebionis coronaria*)	
	Ong choy (*Ipomoea aquatica*)	
	Sweet potato (leaf) (*Ipomoea batatas*)	
	Ridged luffa (*Luffa acutangula*)	
	Wolfberry (*Lycium* sp.)	
	Watercress (*Nasturtium officinale*)	

Vegetative structure

As the summary of species by plant growth habit suggests, the vegetation of gardens was not, in general, structurally complex. Except for fruit trees, small or large trees were found on only seven of the 61 residential lots in the study. Few shrubs, vines or even fruit trees were found on the lots of Chinese-origin households, 39% of which lacked any woody vegetation. Similarly, on the lots of African American and Mexican-origin households, plantings of woody species—aside from fruit trees, brambles (*Rubus* sp.), blueberry bushes (*Vaccinium corymbosum*) and grapevines—were absent or provided little coverage, were confined to front yards, and/or were often sheared or heavily pruned to control their growth.

Garden size and plant diversity

Neither crop nor ornamental plant richness was significantly related to lot size or to total garden area by group or for the full sample. However, density of crop

Table 8. Plant families with the ten highest rates of representation in the ornamental flora of 61 home gardens in Chicago, by group.

African American		**Chinese-origin**		**Mexican-origin**	
Family	**% of species**	**Family**	**% of species**	**Family**	**% of species**
Asteraceae	15.4	Asteraceae	13.5	Asteraceae	12.7
Lamiaceae	7.2	Asparagaceae	5.8	Asparagaceae	6.7
Asparagaceae	4.3	Liliaceae	5.8	Araceae	4.0
Araceae	2.9	Oleaceae	5.8	Crassulaceae	4.0
Crassulaceae	2.4	Rutaceae	5.8	Malvaceae	4.0
Ranunculaceae	2.4	Cactaceae	3.8	Commelinaceae	2.7
Rosaceae	2.4	Cannaceae	3.8	Cornales	2.7
Amaryllidaceae	1.9	Cupressaceae	3.8	Oleaceae	2.7
Campanulaceae	1.9	Iridaceae	3.8	Rutaceae	2.7
Caprifoliaceae Caryophyllaceae	1.9	Orchidaceae Pinaceae	3.8	Balsaminaceae Begoniaceae	2.0
Cornales	1.9	Rosaceae	3.8	Ericaceae	2.0
Euphorbiaceae	1.9	Solanaceae	3.8	Euphorbiaceae	2.0
Malvaceae	1.9	Xanthorrhoeaceae	3.8	Lamiaceae	2.0
Pinaceae	1.9		3.8	Ranunculaceae	2.0
Plantaginaceae	1.9			Rosaceae	2.0
Poaceae	1.9			Solanaceae	2.0
Saxifragaceae	1.9				2.0
Solanaceae	1.9				
	1.9				

taxa was exponentially related to total cultivated crop area, and the log of density was negatively correlated with the log of total cultivated area ($r^2 = 0.74$, $P < 0.001$; Fig. A). Ornamental plant species density was also exponentially related to ornamental plant area, and the log of density was negatively correlated with the log of area ($r^2 = 0.55$, $P < 0.001$; Fig. 3B).

Interview findings: Factors and processes shaping the plant diversity of home gardens

Findings from the qualitative interviews with gardeners confirm and enrich the results from the analysis of quantitative data on the spatial structure and species composition of the 61 home food gardens in the study.

Ethnic and family culture

The crop plant assemblages found in the gardens of African American gardeners—particularly those who had migrated from the American South—were associated with Southern culinary traditions (Taylor and Lovell, 2015). For later generations of African American gardeners, ties between Southern culture and garden diversity were more tenuous than they were for first generation migrants, and other culinary and gardening discourses shaped the form and species composition of their gardens. Two of the Chicago-born African American gardeners were Master Gardeners (individuals who have received intensive training in home horticulture from a university in the USA or Canada (AHS, 2015)) and members of a local gardening club. Their gardens housed diverse ornamental plant collections in addition to food plants, which included heirloom tomato varieties not found in other gardens. Another native Chicagoan, Ms. Lowell (a pseudonym, like all names used to identify gardeners in this paper) drew her culinary and gardening inspiration from television programs. She attempted to 'channel' P. Allen Smith, a popular gardening communicator, in the design of her garden, but Martha Stewart was her primary mentor for both home and gardening activities. The Chicago-born Ms. McDaniels reminisced about the large gardens of her Southern-born relatives on the city's South Side but actively participated in local and national virtual communities of gardeners through on-line groups, including the Chicago-based Advocates for Urban Agriculture. She consulted these groups for gardening advice, exchanged seeds through them, and also secured plants and other materials for her garden through the Freecycle Network™. Ms. Fouret's parents, who were not gardeners, were home cooks who excelled in the culinary traditions of their native Mississippi and Louisiana. However, Ms. Fouret, California-born and Chicago-raised, considered herself to be a 'foodie' with a developing appreciation for wine; the edible plants in her backyard garden reflected that identity. For these gardeners, lifestyle (Pickett et al., 2011) rather than ethnic identity was a major driver of the species composition of their gardens.

Mexican-origin gardeners, all of whom were migrants, grew a wide range of herbs, chili pepper varieties and other plants associated with the culinary traditions of their places of origin within Mexico (Taylor and Lovell, 2015). A total of seven of the gardeners in the study, for

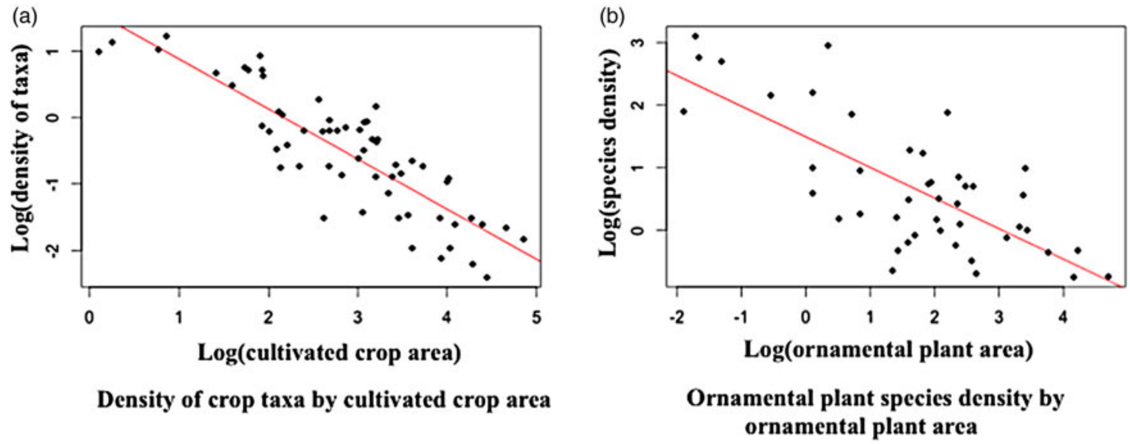

Figure 3. Log–log relationships between (A) crop species density and cultivated crop area ($n = 61$, $r^2 = 0.74$, $P < 0.001$) and (B) ornamental plant species density and ornamental plant area ($n = 44$, $r^2 = 0.55$, $P < 0.001$) for home food gardens in Chicago.

example, grew *pápalo* (*P. ruderale*), a pungent herb popular in the Mexican states of Guerrero and Puebla. Two of these gardeners sold *pápalo*, accounting for its dominance in their gardens and its first place ranking in the proportional abundance data for food crops in the gardens of Mexican-origin households. Mrs. Rodriguez, who was from Guerrero, cultivated not only *pápalo* but also *pipicha* (*Porophyllum linaria*) and a third species of culinary herb that she called *chichihuate* but which was not present in her garden at the time of data collection. She also grew two leguminous plants native to southern Mexico, *chipilín* (*Crotalaria longirostrata*) and *guaje* (*Leucaena* sp.) in her small backyard garden. Mr. Gutierrez grew tropical corn (*Zea mays* subsp. *mays*) and used the leaves to make *corundas*, a tamale-like dish indigenous to the state of Michoacán (Taylor and Lovell, 2015). Attaining a height of three or more meters before tasseling in September, tropical corn is a striking botanical feature in Chicago neighborhoods, potentially acting as a signifier of regional and ethnic identity and reifying shared agricultural and culinary knowledge.

Ethnic food culture and preferences most strongly influenced the species composition of Chinese-origin households' gardens. Regional differences in crop plant assemblages were not noted, as they were for Mexican-origin gardeners, because all participating gardeners were from the same area in southern China. Gardeners reported they preferred Chinese to 'American' vegetables. As one gardener stated, 'I really don't eat American vegetables.' Chinese-origin gardeners also had a productionist approach to gardening that influenced their planting decisions. When asked her annual household income, one gardener retorted, 'It's very little; why else would I have to grow my vegetables?' Another gardener grew food because, 'There is the land to use. It would be a waste if I didn't use it.' These gardeners grew vegetables that could not be purchased locally, were deemed to be of poor quality or to be too expensive in local stores, or had other desirable characteristics that made them worthy of cultivation, such as the storage qualities of winter melon. This productionist orientation toward gardening may contribute to the low abundance of non-food plants in Chinese-origin households' gardens, which Mrs. Cheung linked to Chinese cultural identity: 'Chinese people usually plant vegetables, and Americans plant flowers.' With assimilation, however, values may change along with the symbolism of domestic landscapes, resulting in a generation gap. Ms. Cheung's son, for example, apparently wanted her to garden like an American, 'My son complains that I shouldn't garden and should plant flowers.'

Not all Chinese-origin gardeners grew only traditional crop species or varieties or focused solely on production. Mrs. Kuo, for example, grew potatoes (*Solanum tuberosum*) and spinach (*Spinacia oleracea*) in addition to a wide range of more traditional Chinese crops. Her garden also had the largest ornamental plant area and the second highest number of non-legacy ornamental species (nine) of all gardens of Chinese-origin households. Mrs. Kuo appeared to be more assimilated into mainstream American culture than most of the other Chinese-origin gardeners in the study. She easily engaged the primary author in conversation in English during the garden survey, and her front yard featured not only a small planting of hot peppers but also a large display of flowering annuals which, she said, elicited compliments from passersby who sometimes stopped to photograph it.

Not surprisingly, family culinary traditions and food preferences further influenced the species composition of gardens. One African American gardener grew eggplant specifically for eggplant Parmesan, while another grew tomatoes for salsa for tacos, which were her grandchildren's favorite food. Mrs. Cole, an 81-year-old gardener originally from Arkansas, grew all of the five or six vegetables required for her vegetable soup except corn. Mrs. Rodriguez reported that she grew 'a little lime tree

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because I like to drink the leaves in tea in the morning,' while Mrs. Hernandez and Mr. Guerrero both grew cucumbers for their children, who enjoyed eating them with lime and chili powder. Mrs. Chan, a Chinese-origin gardener, planted an Asian pear tree simply because, as she said, 'I like to eat pears.'

Germplasm acquisition

Gardeners reported a wide range of practices and strategies related to the acquisition and maintenance of crop and ornamental plant diversity in their gardens. The majority of the crop taxa grown in the gardens of Chinese-origin households were grown from seed (Taylor and Lovell, 2015). Only nine taxa were reported to be purchased as plants or starts. All 23 Chinese-origin gardeners saved the seed of at least some of their crops, most often those of cucurbits and beans, which were easier to collect than the seeds of leafy crops. The original source of saved seed was identified for 108 crop records; reported sources included China (58.3%), friends (21.3%) or local stores (20.4%), typically in Chinatown. Seeds from China included those purchased directly from commercial seed houses or procured through friends and relatives. Gardeners saved seed from the same crops year after year.

A smaller percentage of plants in the gardens of Mexican-origin households were grown from seed; of 172 crop records for which the source—purchased plant or seed—was identified, 59 (34.3%) were grown from seed by the gardener. Of the 59 seed-grown crops, 15 (25.4%) were grown from seed directly from Mexico, 9 (15.3%) from saved seed originally from Mexico and 35 (59.3%) from saved seed from other sources, including tomatoes and peppers purchased at local markets. Two Mexican-origin gardeners also reported they had received seeds for green beans and squash from their Chinese-origin neighbors. Attitudes toward transporting germplasm across the border with Mexico varied. One Mexican-origin gardener with a house in Mexico refused to bring back plants or seeds for fear of being stopped at the border. Two others, however, regularly imported seed for *pápalo* or tropical corn, and Mrs. Rodriguez, who also had a house in Mexico, planned to plant a papaya—grown in her Chicago garden from the seed of a particularly flavorful fruit purchased in a local grocery store—in her garden in Mexico. Only ten of the 19 Mexican-origin gardeners (52.6%) saved seed, but even fewer African American gardeners—five out of 17 (29.4%)—saved seed, most of which appeared to be originally derived from commercial sources.

African American and Mexican-origin gardeners accumulated the sometimes-diverse ornamental flora of their gardens from a variety of sources using a wide range of strategies. Plants were acquired as seeds, transplants, cuttings and divisions from commercial sources and through social networks. Garden plant diversity was not necessarily correlated with financial resources (Taylor and Lovell, 2015). Some gardeners with meager financial resources but high social capital, such as Mrs. Murphy, who had an ornamental plant collection of 51 species, drew on networks of friends, family, acquaintances and non-government organizations in addition to market sources to assemble their garden flora. On the lots of some multifamily buildings, more than one household contributed to the richness of the flora and the management of the garden. Mrs. García and her husband, for example, planted and cared for a vegetable garden in the backyard of their apartment building, while their landlady planted and managed herbaceous perennials and flowering shrubs in both the front and backyards. Similarly co-managed spaces were identified in the African American and Chinese-origin study neighborhoods.

Discussion

This study builds on published, preliminary findings from an initial sample of 31 gardens (Taylor and Lovell, 2015). It corroborates those findings and expands on them. In doing so, it addresses significant gaps in the literature on the contributions of domestic gardens to urban ecosystems. It is the first study to examine total plant diversity in the context of urban residential food production in the USA and to compare the diversity-related practices of three groups, African American, Chinese-origin and Mexican-origin gardeners. By combining plant inventory and abundance data with information from interviews conducted with gardeners, it explores some of the factors—including ethnic and regional culture, processes of assimilation, social networks, multifamily residency and popular culture—and some of the tradeoffs specific to growing food in the city that may influence domestic garden diversity. Furthermore, the study focuses on ethnic and migrant households living in diverse housing types in inner city neighborhoods. These are policy relevant groups and spaces that have been overlooked in the research on urban biodiversity and urban ecosystems in general.

These gardeners—and food gardeners overall—may have landscape values that diverge from those of city residents in general, with implications for garden composition and structure and cascading impacts on ecosystem processes at higher levels. While the general population may, for example, prioritize aesthetics, low maintenance, floral biodiversity and neatness in domestic gardens (Larson et al., 2015), food gardeners are more likely to place a higher value on provisioning functions, with implications for garden structure and composition. In this study, Chinese-origin households appeared to prioritize production over aesthetics and floral biodiversity, resulting in low richness and abundance of ornamental species in their gardens. Ethnic or migrant gardeners may also place greater value on the contribution of residential gardens to the reproduction of traditions and heritage more than the population at large (Mazumdar, 2012), for whom this cultural service is reportedly relatively unimportant (Larson et al., 2015). Study findings suggest that with assimilation the value accorded this service may decline.

Garden plant diversity in the study was linked to the cultural and lifestyle diversity of participating gardeners. For immigrants, particularly recent immigrants, ethnic and regional culture had a large impact on garden structure and on the composition and abundance of food taxa, resulting in the development of culture-specific crop plant assemblages in gardens. Similar, culturally based assemblages of food plants have been identified in US cities in the community garden plots of African American, Asian, and Hispanic gardeners (Clarke and Jenerette, 2015), Hmong refugees (Corlett et al., 2003) and Oaxacan indigenous immigrants (Minkoff-Zern, 2012) and in the backyard gardens of Vietnamese immigrants (Airriess and Clawson, 1994).

In this study, NMDS ordination of study gardens based on relative crop abundance resulted in the clustering of gardens by ethnic group. The gardens of Mexican- and Chinese-origin households were relatively tightly clustered in ordination space, indicating a greater degree of similarity in the species composition of their gardens compared with those of African American gardeners. The latter group was more demographically heterogeneous than the Chinese- and Mexican-origin gardeners participating in the study, all of whom were foreign born. The majority ($n = 9$) of the African American gardeners were second or third generation Chicagoans; seven had migrated to Chicago from the American South 40 or more years earlier. While Chicago-born gardeners continued to grow crops associated with Southern foodways, such as collards, they grew other crops as well, as did some Southern born gardeners. A subset of gardeners in both subgroups—exclusively women—identified as lifestyle gardeners who prioritized aesthetics, floral diversity, experimentation with plants, and communing with nature in the space of the garden. Their gardens tended to be more diverse than their counterparts—almost exclusively men—who equated gardening with farming.

In addition to their acknowledged productive and cultural functions, home gardens in developed countries are increasingly recognized as sites for the *in situ* conservation of crop plant diversity (Eyzaguirre and Bailey, 2009), and the gardens of immigrants in particular may be 'hotspots' for agrobiodiversity that can potentially serve as a genetic resource for crop development (Gladis and Pistrick, 2011). Findings from this study suggest that even the inner city home gardens of migrant households in Chicago may conserve agrobiodiversity with roots in developing countries (Taylor and Lovell, 2015), which encompass centers of diversity for many economically important crops (Kloppenburg, 2005). This agrobiodiversity may, in fact, be more concentrated in urban areas in the USA than in the gardeners' places of origin. Clarke et al. (2014), for example, identified 100 edible species in 102 gardens along a suburban to rural transect in the Beijing Municipality of China. In Chicago, 58 edible species were inventoried in the 23 much smaller urban gardens of Chinese-origin households participating in this study.

Chinese-origin gardeners in Chicago may be not only conserving germplasm. Through simple mass selection, they may also be developing new landraces of culturally important crops adapted to local environmental conditions and preferences. Gardeners in this study reported that they saved seed from the 'best' plants: the largest melons or the longest yardlong bean pods. If gardens were isolated, selection over time could result in the loss of genetic diversity. Garden populations of a crop species, however, could be considered to constitute a metapopulation, with gene flow between gardens facilitated by the clustering of gardens in the urban landscape, the sharing of germplasm by gardeners, and the activities of pollinators. The introduction of seeds from outside sources, e.g., China or domestic commercial sources, and by successive waves of migrants from different regions of China and Asia may further diversify the gene pool of crop populations in Chicago, potentially making these locally adapted populations more resilient in the face of climate change and other selection pressures (Aitken and Whitlock, 2013). With assimilation and generational change in the Chinese-origin community, however, diversity may be lost over time. Further research with US-born Chinese-origin gardeners is needed to test this hypothesis.

In general, urbanization, has been shown to increase overall plant diversity because of the introduction of non-native species (Faeth et al., 2011). Our findings indicate home food gardeners are potentially important yet often unappreciated actors in shaping that diversity. In the aggregate, the gardens in this study supported a concentrated number of diverse plant species, and we found an inverse, exponential relationship between both density of crop taxa and cultivated ground area and ornamental plant richness and ornamental plant area. We identified a total of 123 edible plant taxa representing 102 species from 25 families and 288 ornamental species from 85 families, for a combined total of 387 unique species from 90 families. The aggregate area of the residential lots included in this study was 2.1 ha, yielding 184 unique species per hectare, a much higher level of species richness per unit area than the 108 species per hectare found in a comparable study of community gardens in Los Angeles (Clarke and Jenerette, 2015). A far higher number of plant species ($n = 1166$) were identified in an identical number of residential gardens ($n = 61$) in Sheffield, UK. However, the area surveyed in that study was not reported, and all vascular plants on the lot were surveyed, including planned and unplanned or associated species (Smith et al., 2006).

An appropriate 'native' comparison for our purposes would be prairie, the dominant ecosystem in Chicago prior to European settlement. The richness of the aggregate 2.1 ha of residential property inventoried in this study was comparable to or exceeded that of a 34 ha prairie remnant, the Wolf Road Prairie, located 22 km west of Chicago (Sluis, 2002). However, the vast majority of the garden species (90.4%) were not native to the Chicago region per Swink and Wilhem (Swink and Wilhelm, 1994), indicating replacement of natives by non-natives in study gardens. (While the associated or unplanned flora of the gardens was not surveyed, it may be expected to consist primarily of common lawn flora and ruderal or competitive non-natives with a minority of native species.)

Enrichment of the flora through the replacement of native by non-native plants does not necessarily enhance biodiversity at higher trophic levels (Faeth et al., 2011). Compared with non-native plantings, native plant landscaping in urbanizing settings has been found to have a positive impact on native arthropod diversity and, consequently, on native avian diversity (Burghardt et al., 2009), though exotic trees may be underestimated as a resource for native birds (Gray and Van Heezik, 2015). Replacing native with non-native plants can also lead to the biotic homogenization of urban ecosystems at larger scales, as assemblages of plant species across cities with similar climates converge through the activities of consumers and the horticultural industries (McKinney, 2006). Consequently, though the gardens included in this study supported a large pool of non-native, cultivated plant species, they may make little contribution to aboveground biodiversity at the local or regional levels. At the same time, the gardens of the lifestyle gardeners and immigrant gardeners in the study appeared to harbor crop and ornamental species unlike those observed in adjacent yards, suggesting that they do enrich the local flora, though with unknown consequences for biota at higher trophic levels. The impact of food gardens on belowground biodiversity is similarly unknown. While the addition of organic matter to garden soils may favor the development of diverse microbial communities, frequent tillage and the use of chemical fertilizers—common practices among the gardeners in this study—may reduce soil microbial diversity in agroecosystems, with associated negative impacts on the ecosystem services microbes provide, e.g., nutrient cycling (Brussaard et al., 2007).

Beyond the diversity of garden flora, study findings suggest that food gardeners' unique concerns differentiate them from other urban residents in ways that drive the vegetative structure of their gardens, with implications for urban biodiversity conservation and ecosystem processes. Because light is a limiting factor in urban food production (Wortman and Lovell, 2013), the shading of growing areas by buildings, trees, and other vegetation was a central concern of gardeners, and the few gardeners who had large trees on their lots expressed a desire to remove them. This attitude stands in marked contrast to the preferences of urban residents in general, who identify the shade provided by trees as an important ecosystem service of residential gardens (Avolio et al., 2015; Larson et al., 2015), particularly in warm climates (Avolio et al., 2015). It also contradicts the dominant discourses on the urban forest in planning and research, which position it as a universally desirable public good, which mitigates urban heat island effects (Akbari et al., 2001) and provides habitat for vertebrates and invertebrates (Nowak and Dwyer, 2007), among other benefits. The lack of trees in inner city neighborhoods has been attributed to high housing density and low household income (Iverson and Cook, 2000) and to a lack of investment in the urban forest in low income and ethnic minority neighborhoods (Heynen et al., 2006). The removal of healthy trees from private urban lots has also been ascribed to a "desire to enact moral imperatives" based in nativist ideologies (in the case of non-native trees) and to changes in fashion (Kirkpatrick et al., 2013). Our study suggests that, at the scale of the residential lot, another factor—food production—may also account for an absence of urban trees. The individual household's decision not to plant trees in favor of producing food potentially has impacts on ecosystem processes at higher levels now and in the future because of legacy effects, particularly in areas with large numbers of home gardens, e.g., Chicago's Chinatown (Taylor and Lovell, 2012). With estimates of up to 33% of households in urban areas in the USA participating in food production (Smith et al., 2013), the magnitude of these impacts may be underappreciated.

For potentially similar reasons, gardens in this study overall lacked a well-developed shrub layer, and the gardens of Chinese-origin households and some other gardens also lacked perennial groundlayer vegetation. Layered vegetation in urban areas enhances the diversity of vertebrate and invertebrate species (Goddard et al., 2010; Sattler et al., 2010) and in the aggregate may affect diversity and processes at broader scales. Within the garden, the absence of such vegetation may not only reduce biodiversity but also productivity. In other agroecosystem types, the addition of areas of diverse perennial plants, particularly flowering plants, has been demonstrated to increase pollination and predation services to adjacent field crops (Nicholls and Altieri, 2013).

Fruit trees and fruiting vines, shrubs, and subshrubs were one exception to the lack of vegetative structure in the home food gardens included in this study. Fruit trees in particular were more abundant in the gardens of Mexican-origin households. The vertical and layered plantings of Chinese-origin households' gardens were a second exception. These strategies for increasing and diversifying production area may increase biodiversity at higher trophic levels by providing more material and spatial resources and ecological niches for insects, birds, and mammals, as do the small-scale agroforestry systems found in tropical homegardens (Scales and Marsden, 2008). The clustering of such gardens in ethnically homogeneous neighborhoods may strengthen their impact on urban ecosystem processes.

Overall, this study indicates that additional research on urban domestic gardens is needed if the full extent of their potential positive contributions to urban ecosystems is to be realized and their negative contributions are to be minimized. This study included only residential lots with food gardens. Because of the lack of any baseline data for residential gardens in Chicago, the inclusion of matched lots without a food garden could, in future work, provide a basis for comparing the diversity of each garden type and for identifying the potential factors—and tradeoffs in ecosystem services—accounting for differences in diversity. Additional research is needed on the impacts of garden composition, features, and structure, e.g., the arbor systems of the gardens of Chinese-origin households and domestic agroforestry systems, and soils and soil management practices on ecological processes and ecosystem characteristics beyond plant diversity. By illuminating social factors and processes contributing to the diversity of urban domestic gardens, this study—with its purposive sample and semi-structured interview format—develops hypotheses that can be tested in future quantitative studies employing large representative samples systematically selected from a wide range of population subgroups and housing types. Such research would contribute to a broader understanding of the contributions that domestic gardens make to ecosystems at the level of the neighborhood and the city. Findings from this study also suggest that seed saving and seed sharing practices and networks and the genetic composition of urban crop populations are potentially fecund areas of research. Exploration of these topics would help to illuminate the role of urban gardens in conserving crop plant diversity, the impact of selection on crop plant genetics and productivity, gene flow between gardens, and introgression of new germplasm. Such research could contribute more generally to our understanding of plant population genetics in urban environments. Finally, participatory, *in situ* experimental research exploring the tradeoffs between food production and ecological benefits could inform the development of outreach programs to gardeners that would help them garden productively in ways that enhance urban biodiversity and ecosystem processes. Such research must engage ethnic and migrant groups—and food gardeners as a whole—whose domestic gardening activities have been invisible to academics, non-government organizations, and policymakers (Taylor and Lovell, 2014; Taylor and Lovell, 2015). Working with these stakeholders to incorporate more ecological functions into their gardens will ultimately be more productive than working against their landscape preferences and values (Larson et al., 2015).

Conclusion

As a major land use, domestic gardens have the potential to make large, positive contributions to urban ecosystems. However, efforts to capitalize on these gardens as part of the green infrastructure of the city must recognize the different cultural and social roles they play for diverse urban populations. Academics and policymakers must also acknowledge and seek to address the real tradeoffs that occur as increasing demands are placed on these domestic ecosystems, in the face of increasing food insecurity, climate change and environmental degradation.

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