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Research

Gardener demographics, experience, and motivations drive differences in plant species richness and composition in urban gardens

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ABSTRACT. Urban agriculture has received considerable attention for its role in supporting biodiversity and ecosystem services, and health and well-being for growing urban populations. Urban gardens managed with agroecological practices and higher plant diversity support more biodiversity and may support higher crop production. Plant selection in gardens is a function of temperature and environmental conditions and also depends on gardener socio-demographic characteristics, motivations for gardening, and gardening experience. In this study, we examined how plant richness and composition vary with gardener socio-demographic factors, gardening experience and garden use, and gardener motivations. We focused on the socio-demographic factors of age, gender, education, and region of national origin, used information on years spent gardening and hours spent in gardens as a proxy for gardening experience, and collected information on motivations, as well as crop and ornamental plants grown by individual gardeners. We found that gender, region of origin, time spent gardening, and gardener motivations all influenced plant richness or composition. Specifically, women plant more plant species than men, especially of ornamental plants, and individual gardeners motivated by nature connection tend to plant strongly different plant compositions in their gardens. We also found that region of national origin strongly influences crop composition. In contrast to previous studies, we did not find that gardeners more motivated by food grow a higher proportion of or more crop species compared with ornamentals. Thus we show that multiple socio-demographic characteristics and motivations influence garden plant communities, and thus assuring access to gardens for all groups may boost plant richness and support ecosystem services in gardens.

Key Words: *age; agriculture; biodiversity; California; food access; gender*

INTRODUCTION

Urban agriculture has received considerable attention for its role in supporting biodiversity and ecosystem services for growing urban populations. Sustainable urban agricultural systems, including community gardens, can safeguard food production and protect biodiversity. Specifically, urban gardens managed with agroecological practices and higher plant diversity support higher bird and insect diversity (e.g., Bolger et al. 2000, Gibb and Hochuli 2002, Matteson et al. 2008, Uno et al. 2010, Gardiner et al. 2014, Pardee and Philpott 2014, Philpott et al. 2014, Lin et al. 2015, Quistberg et al. 2016). Moreover, gardens with a high diversity of cultivated plants and other species may support enhanced pollination, pest control, and climate regulation services (Lin et al. 2015, Egerer et al. 2019*a*), all of which can boost crop production. This local crop production can enhance fresh food access (Alaimo et al. 2008, Altieri and Nicholls 2018) and improve nutrition for gardeners and their families (Blair et al. 1991, Macintyre et al. 2003). Gardens also promote physical and mental health by providing opportunities for exercise and meaningful human-nature interactions (Macintyre et al. 2003, Saldivar-Tanaka and Krasny 2004, Wakefield et al. 2007, Kingsley et al. 2009). Thus, urban gardens are an important component of green infrastructure that simultaneously support biodiversity conservation, ecosystem services, and enhanced human well-being. It is critical to learn more about both the ecological and social drivers of the cultivated plant species diversity and composition that form the ecological foundation of urban gardens, in order to maintain and enhance these social and biodiversity benefits evenly across urban landscapes.

The diversity and composition of plant communities within urban gardens is strongly influenced by gardener decisions related to vegetation management. Community gardens are often a collection of allotments wherein individual gardeners or families manage a single plot, leading to the potential for high spatial and temporal vegetation turnover. Each gardener may manage their plot differently, and diverse management practices may drive differences in plant or floral diversity, thereby influencing overall biodiversity at a site (Kinzig et al. 2005, Iuliano et al. 2017). Variation in plant selection is likely a function of gardener socio-demographic characteristics, motivations for gardening, and gardening experience. Although biological and physical conditions of gardens, e.g., temperature, precipitation, or variable climatic conditions, may affect plant growth and survival, gardener desires for specific crops or ornamentals may have even stronger influences on garden plant composition (Taylor and Lovell 2015, Egerer et al. 2019*a*). Gardeners may plant culturally appropriate vegetables and medicinal plants difficult to access in local grocery stores (Baker 2004), and individuals from different ethno-cultural backgrounds may prefer different types of plants and vegetative arrangements, leading to differences in crop composition (Clarke and Jenerette 2015, Burdine and Taylor 2018). Social differences due to ethnicity, age, or class can lead to differences in cultivated plant richness (Bernholt et al. 2009) and

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low-income gardeners with less access to markets may grow more crops than ornamentals (e.g., Clarke et al. 2014). Gender may drive differences in plant richness or composition because of gendered household or agricultural roles or differences in benefits that women and men gain from gardening (Richardson and Mitchell 2010, Taylor et al. 2017). Moreover, the range of experience in, or knowledge of, agriculture among gardeners may lead to differences in plant diversity, composition, or management (Clarke et al. 2014).

Although various social factors, including demographics and motivations for gardening, are individually linked to garden plant diversity, little research has connected multiple social factors to plant diversity and composition within gardener plots. This is because most studies have focused on describing the (1) garden vegetation characteristics, irrespective of descriptive characteristics of the people that manage the garden (e.g., Philpott et al. 2014); (2) socio-demographic characteristics of the gardeners, without measuring biodiversity within their plots (e.g., Saldivar-Tanaka and Krasny 2004, Burdine and Taylor 2018); and (3) plants cultivated by a single social group within one or a few gardens (e.g., Corlett et al. 2003, Baker 2004) rather than broader patterns across diverse social groups. Thus, despite our understanding that gardens are important social spaces (Baker 2004, Saldivar-Tanaka and Krasny 2004, Čepić and Tomićević-Dubljević 2017) and support biodiversity in cities (Matteson et al. 2008, Gardiner et al. 2014, Lin et al. 2015, Quistberg et al. 2016, Egerer et al. 2017), we still lack knowledge of how social differences among gardeners determine plant diversity and composition, vegetation features that may have critical influence over ecosystem service provisioning, such as food production (Taylor et al. 2017). Having a better understanding of how socio-demographic factors influence crop and ornamental richness and composition within gardens may provide key information for how to maintain high plant diversity and thus support biodiversity and ecosystem services in gardens.

We aim to advance our knowledge of the relationships between gardener socio-demographics, experience, and motivations, and plant diversity and composition within urban gardens. Specifically, we focus our study on answering the following research question: How does plant richness and composition vary with (a) gardener socio-demographic factors, (b) gardening experience and garden use, and (c) gardener motivations for gardening? We focused on the socio-demographic factors of age, gender, education, and region of origin. We used information on years spent gardening and hours spent in gardens as a proxy for gardening experience and use. We collected information on gardener motivations as well as crop and ornamental plants grown by individual gardeners. We predicted that plant, and especially crop composition, would differ with factors such as gender or region of national origin given the importance of culture for garden plant selection. We predicted that crop, ornamental, and total (crop plus ornamental) plant richness might be greater for gardeners that spend more time in their plots given the greater labor capital available for plant care. We also predicted that gardeners motivated primarily by food would plant more crops, whereas gardeners motivated by recreation, environmental, and nonfood-based needs would plant more ornamentals.

METHODS

Study region and sites

We conducted this research in 20 urban, community, allotment gardens in Monterey (36.2400° N, 121.3100° W), Santa Clara (37.3600° N, 121.9700° W), and Santa Cruz (37.0300° N, 122.0100° W) counties, in California, USA between June and October 2017. The gardens have been used as sites for ecological studies since 2013 (e.g., Quistberg et al. 2016, Plascencia and Philpott 2017, Egerer et al. 2018, Lin et al. 2018). The gardens range in size from 444 to 15,525 m² and serve between 5 and 92 different gardeners (or gardener families). All gardens are managed with organic practices but vary in age (6–40 yrs), local habitat characteristics, i.e., vegetation cover, crop richness, and floral abundance, and landscape surroundings (Egerer et al. 2018). The population is ethnically diverse, including recent immigrants (from countries including Mexico, El Salvador, Iran, Bosnia, and Vietnam) and long-time residents of California.

Gardener surveys

We designed survey questionnaires to assess gardener socio-demographic backgrounds, experience with gardening, motivations for gardening, and the plant species that each gardener grows (Appendix 1). For the purposes of this study, we defined a gardener to be any individual found tending plants or soil, watering, or harvesting crops from a plot in the urban, community, or allotment gardens that we visited. To learn about gardener socio-demographic characteristics, we asked gardeners to provide information on age, gender, highest level of completed education, household income, and national origin of gardeners or their parents as a potential indicator of differences in ethno-cultural variables or foodways. To learn about gardener experience, we asked about years of gardening experience, and number of hours per week spent in the garden. To learn about gardener motivations, we asked gardeners to list the top reason why they garden (open-ended). We collected continuous data on age, years gardening, and hours per week spent gardening, and categorical data on gender, education level, and household income, as well as open-ended answers about motivations for gardening and national origin. To learn about the plant species gardeners are growing, we prompted gardeners with a list of commonly cultivated crop and ornamental species (based on four years of vegetation surveys from the study sites), and then asked gardeners to list any crops or ornamental plants that we had not mentioned. Crops included food crops, herbs, spices, species used for tea, as well as one species used for dye. Ornamentals included flowers and other decorative plants. Although spontaneous noncultivated vegetation (or "weeds" to some gardeners) are an important component of the plant community in urban gardens we did not ask about these plant species for two reasons. First, richness of noncultivated plants, in particular, may be underestimated by gardeners compared with cultivated species (e.g., Muratet et al. 2015, Egerer et al. 2019*b*). Second, the definition of what is a weed vs. an edible or medicinal plant may strongly differ depending on cultural or demographic background (e.g., Saldivar-Tanaka and Krasny 2004).

We surveyed 185 gardeners, but not all gardeners answered all questions. A substantial fraction of gardeners (~20%) did not provide information about household income, thus we chose not

Table 1. Demographic characteristics of gardeners surveyed from California central coast urban gardens. Variables included as explanatory variables in the analysis.

Demographic factor	Coded variables included in analysis	Survey answers
Age	22–85 years old	Age at the time of survey
Gender	Male (n = 79), Female (n = 87)	Gender
Education	No school (n = 7)	No formal schooling
	Prehigh school (n = 18)	Elementary school, middle school, some high school
	High school (n = 19)	High school graduate
	Posthigh school (n = 45)	Trade/technical/vocational training, some college, associate degree
	University (n = 44)	Bachelor's degree
	Graduate degree (n=44)	Master's degree, professional degree, Doctorate degree
Region of origin	North America (n = 61)	Canada, United States
	Latin America (n = 45)	Chile, El Salvador, Mexico, Peru
	Europe (n = 28)	Armenia, Bosnia, Bulgaria, Czech Republic, England, France, Germany, Ireland, Italy, Norway, Poland, Romania, Russia, Spain, Switzerland
	Asia / Pacific Islands (n = 27)	Cambodia, China, India, Japan, Korea, Malaysia, New Zealand, Philippines, Taiwan, Vietnam
	Middle East (n = 5)	Iran, Iraq
Years gardening	0 to 85 years	
Hours per week spent in garden	0.5 to 60 hours	

to include income as a factor in our analysis. We included only those surveys where gardeners provided information on all other variables, and where there were at least five individuals in each category for the categorical variables. This resulted in a total of 166 surveys from 19 gardens in our analysis. Surveys were given in English (n = 126), Spanish (n = 39), and Korean (n = 1) and either read out loud by the researcher in person (n = 140) or by phone (n = 3), filled out by the gardener on their own (n = 22), or read out loud to a gardener by another gardener (n = 1).

Data analysis

We used a qualitative inductive approach to search for common answers and themes in gardener responses, and then to code or summarize the responses to open-ended questions (Tables 1 and 2; Thomas 2006). Gardeners surveyed were diverse, representing a large range of all socio-demographic variables examined (Table 1). The age range was nearly 63 years, and education level ranged from no formal education to a graduate degree (PhD). Gardeners (or their parents) hailed from 36 different countries, yielding five major regions of national origin (Table 1). Gardeners provided a wide array of motivations for gardening, yielding five major categories (Table 2). Different demographic variables may co-vary or may interact in certain ways to influence plant richness and composition. Although examining differences among demographic variables was not a main aim of the paper, we include some information about relationships among variables in Appendix 2.

We used generalized linear mixed models (GLMM) to test the differences in total plant, crop, and ornamental species richness, and the proportion of all plants that were crops based on socio-demographic features (age, gender, education, region), experience (years gardening, hours spent in garden), and motivation. We focused our analysis at the individual garden plot scale to understand how gardener backgrounds shape the agrobiodiversity of plants within their plots, as this is the scale at which plant management decisions are most often made within urban, community, allotment gardens. We created four global models with either (1) plant species richness, (2) crop species richness, (3) ornamental plant species richness, or (4) the proportion of cultivated plants that were crops as the dependent variables, and age, gender, region, education level, years gardening, hours spent gardening, and motivation as independent variables. We also included garden as a random factor because plant management and choice may be influenced by temperature, soil, environmental variability, or age of gardens (e.g., Taylor and Lovell 2015), and because gardener plant choice may be influenced by who else gardens at an individual site (e.g., Agustina and Beilin 2012). We chose to include both crop and ornamental richness as well as the proportion of all plants that are crops because gardener plot sizes differ and that may impact species richness values; examining proportion also allowed us to control for differences in plot size. All statistical analysis was conducted in R version 1.1.456 (R Development Core Team 2018). We checked the variable inflation factor with the "vif" function in the "car" package version 3.0-2 (Fox and Weisberg 2011), and for all global models, all VIF scores were below 2.8. We then used the "dredge" function in the "MuMIn" package version 1.42.1 (Bartoń 2012) to run all iterations of predictor variables, and ran model selection with the AIC scores to select the best models. If any models were within 2 AIC scores of the best model, we use the "model.avg" function to average these top models. We used natural log transformed numbers of total plant species, ornamental plant species, and hours per week spent in the garden to conform to the normal distribution. For the proportion of cultivated plants that were crops we used the "cbind" function to create a variable that included both number of crop species and number of ornamental species. We used a Gaussian distribution for all models.

We assessed differences in plant composition in three ways. First, we created nonmetric multidimensional scaling (NMDS) plots to visualize differences in plant, crop, and ornamental composition based on socio-demographic features (age, gender, education, region), experience (years gardening, hours spent in garden), and motivation. We used a permutational multivariate analysis of variance (PERMANOVA) using the "adonis" function in the "vegan" package version 2.5-4 (Oksanen et al. 2018) to assess dissimilarity among socio-demographic features by comparing the centroid and dispersion of different socio-demographic

Table 2. Codebook for gardener motivations named as a top motivation by urban gardeners in the central coast of California. Codes included as a factor in the model analysis.

Motivation Code	No. of gardeners	Examples of reasons provided
Food	67	food, organic food, vegetables, healthy food, grow my own food, grow peppers for pickling, food I can trust, heirloom, varieties cannot get in store, save money, more economical, financially helps family
Recreation	41	rewarding, builds character, meaningful, tangible, sense of commitment, hobby, stay busy, distraction, something to do, past time, recreation, I like it, I love it, it is fun, it's nice to be in the garden, I like to harvest, favorite activity, fun time, having a good time, pleasure, like growing things
Nature Connection	27	like to watch plants grow, connection to nature, enjoy a sense of growing things, love for plants, having hands in the dirt, magic of growing vegetables, the joy of being in nature, to be outside, spend time outdoors, space, being out in the open, fresh air, big ag is a disaster, Earth, for the environment and society, obvious as a way of living
Health	17	keep fit, do exercise, health, staying healthy, better diet, mindfulness, listening, de-stress, therapy, imagination, uplifts mood, relaxation, rehabilitating self, feeds my spirit, solitary thing to escape reality, Zen factor, cathartic, get away from everything, decompress
Social	14	cultural reasons, connects me to familial roots, avoid losing the tradition, reminds me of my country, reminds me of my father, used to live on a farm, gardened all my life, knowledge sharing and learning, teach kids about where their food comes from, teach kids nature, learn new practices, learning new things, do it for my wife/husband, make friends, social activity, meeting people, be with other gardeners/family/friends, being with others, freedom to socialize, tend a family member's garden

groups. We used Bray-Curtis distances, included each socio-demographic feature as a predictor variable, included garden as "strata," conducted 999 permutations, and made pairwise comparisons with the "pairwiseAdonis" function (Martinez Arbizu 2018). Then, we used an analysis of similarity (ANOSIM) with function "anosim" in the "vegan" package to compare within and between group differences in age, gender, education, region of national origin, and motivations. We used Bray-Curtis distances, ran 999 permutations, and made pairwise comparisons with the "pairwise.adonis" function using a false discovery rate correction for multiple comparisons.

RESULTS

Plant species richness

Gardeners reported 192 plant species across the 19 gardens (13.37 ± 0.57 [SE], 1–40 species per gardener). Gardeners planted 123 crop species (11.71 ± 0.47 [SE], 0–31 crops per gardener) and 68 ornamentals (1.66 ± 0.160 or 0–11 ornamental species per gardener). The most common crop species were tomato (N = 149), squash (N = 118), peppers (N = 111), beans (N = 107), cucumber (N = 92), kale (N = 74), lettuce (N = 71), and carrot (N = 64). The most common ornamentals were sunflower (N = 32), dahlia (N = 20), marigold (N = 20), zinnia (N = 18), and nasturtium (N = 17).

Species richness of all plants, crops, and ornamentals differed with some socio-demographic factors and with gardener experience, but plant, crop, and ornamental species richness did not differ with gardener motivations. Specifically, total plant species richness increased with the number of hours spent in the garden (Fig. 1a). The best model predicting total plant species richness was an average of two top models, one which was the null and the other that included hours spent in the garden (Table A3.1). In the average model, hours spent in the garden significantly predicted increases in total plant richness (z = 2.729, P = 0.006, Table A3.2). Crop plant species richness also increased with number of hours spent in the garden (Fig. 1b). The best model predicting crop species richness was an average of two top models and included education, hours spent gardening, motivation, region, and gender (Table A3.1). In the averaged model, hours spent in the garden significantly predicted increases in crop richness (z = 3.160, P = 0.002, Table A3.2), and European-origin gardeners planted more crops than Middle East-origin (z = 2.344, P = 0.019) and USA/Canada-origin gardeners (z = 2.215, P = 0.0268, Fig. 2a) but no other factors were significant predictors of crop species in the averaged model (Tables A3.2-A.3.5). Ornamental plant species richness significantly differed with gender and with region of origin (Fig. 2b, c), and the best model predicting ornamental species richness was an average of the top four models that included gender, hours spent in the garden, and region of national origin (Table A3.1). Women planted significantly more ornamental plants than men (z = 2.393, P = 0.015), and Asia/Pacific Island-origin gardeners planted significantly fewer ornamental plants than USA/Canada-origin gardeners (z = 2.129, P = 0.033), but there were no other pairwise differences between regions of national origin, and hours spent gardening did not influence ornamental plant richness (Tables A3.2, A3.5).

Fig. 1. Significant predictors of total plant (A) and crop (B) species richness reported by gardeners in urban gardens in the California central coast as determined with generalized linear mixed models (GLMM) selection. In scatter plots, lines show the best fit model.

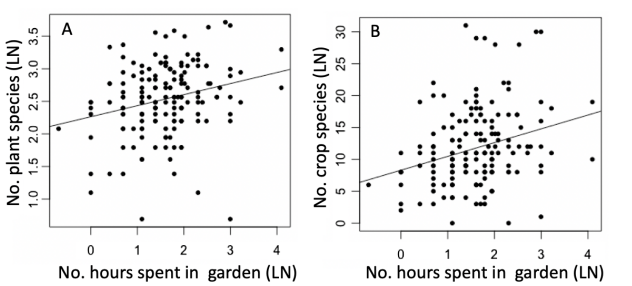


Fig. 2. Significant predictors of crop (A) and ornamental plant richness (B, C) and the proportion of plant species that are crops (D, E) reported by gardeners in urban gardens in the California central coast. In the box plots, the thick line is the median, the box limits are the 25% and 75% percentiles, whiskers show 1.5 times the interquartile range, and points are outliers. Small letters show differences between groups. Sample size for each group listed in Table 1.

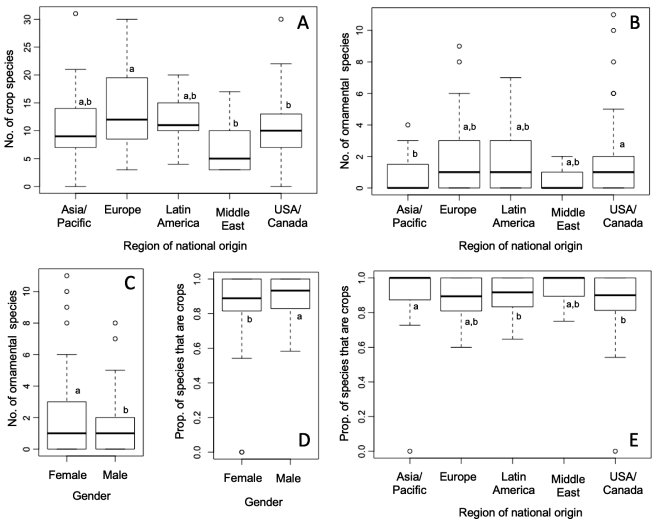
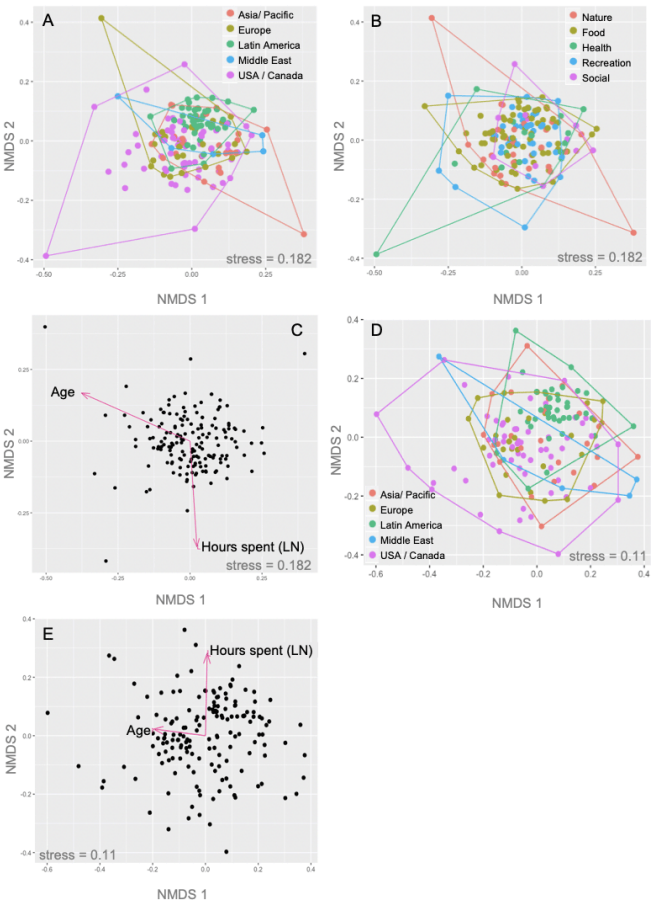


Fig. 3. Nonmetric multidimensional scaling (NMDS) plots showing distribution of all plant composition based on region of national origin (A), motivations for gardening (B), and based on gardener age, and number of hours spent in the garden (C), and crop composition as a function of region of national origin (D), and gardener age and number of hours spent in the garden (E). All panels show only significant drivers of composition. For panels C and E, each vector points to the direction of most rapid change in its corresponding environmental variable within the ordination space, and vector length indicates the relative strength of the relationship. Significant differences in dispersion and community composition are discussed in the text.



Proportion of crop species

Nearly all gardeners (all but two) planted crop species but 66 (or 39.7% of gardeners surveyed) did not grow ornamental plants. On average, 88.6% of total plant species reported by a single gardener were crops. The proportion of crop species reported varied with gender and region of national origin (Fig. 2 d, e). The best model predicting the proportion of crop species was an average of six top models and included gender, region, age, and years of gardening experience (Table A3.1). Men reported a significantly higher proportion of crop plants than women ($z = 2.530$, $P = 0.011$) and Asia/Pacific Island-origin gardeners reported higher proportion of crop plants than Latin American-origin ($z = 2.241$, 0.025) and USA/Canada-origin gardeners ($z = 2.765$, $P = 0.006$). Age and years of gardening experience were not significant predictors of the proportion of crop species (Table A3.2), and there were no other pairwise differences between regions of national origin (Table A3.7).

Plant composition

Total plant and crop composition varied with several socio-demographic factors, but ornamental plant composition did not. According to the PERMANOVA, total plant composition differed with age ($F = 1.77$, $P = 0.05$), region of national origin ($F = 2.63$, $P = 0.001$), hours spent in the garden ($F = 2.23$, $P = 0.011$), and motivations for gardening ($F = 1.38$, 0.042). Different Latin America-origin gardeners tended to grow more similar plant species than did different gardeners from other regions ($P < 0.05$), and Asia/Pacific Island-origin gardeners grew more similar plants to each other than did USA/Canada-origin gardeners ($P < 0.05$; Fig. 3a). Gardeners motivated by nature connection tended to grow more different plants than gardeners motivated by food ($P < 0.05$) or recreation ($P < 0.05$; Fig. 3b). Dissimilarity in crop composition was influenced by both gardener age and time spent in the garden, but these two factors influenced composition in different ways (Fig. 3c). Similarly, crop dissimilarity was driven by age ($F = 2.09$, $P = 0.016$), region of national origin ($F = 2.96$, $P = 0.001$), and hours spent in the garden ($F = 2.54$, $P = 0.005$). Latin America-origin gardeners tended to grow more similar crops to each other than did gardeners from all other regions ($P < 0.05$), and Asia/Pacific Island-origin gardeners grew more similar crops to each other than did USA/Canada-origin gardeners ($P < 0.05$; Fig. 3d). For crop plants,

dissimilarity was influenced by both age of gardeners and time spent in the garden, but in different ways (Fig. 3e). According to the ANOSIM, all plant and crop composition differed with a few socio-demographic features. All plant composition differed with region of national origin ($R^2 = 0.15$, $P < 0.001$) and by motivation for gardening ($R^2 = 0.08$, $P = 0.006$), while crop composition differed with region of national origin ($R^2 = 0.17$, $P < 0.001$).

DISCUSSION

In this study, we show that gender, region of origin, time spent gardening, and gardener motivations all relate to changes in plant richness or composition. Specifically, we found that women cultivate more plant species, especially more ornamental plant species, than men, and that individual gardeners motivated by nature connection tend to differ more in the plants they cultivate compared to individual gardeners motivated by food or recreation who cultivated more similar plant species to each other. We also found that region of national origin is a strong driver of crop composition. Yet, we did not find that gardeners primarily motivated by food grow a higher proportion of crop species, or more crops than ornamentals, in contrast to other studies demonstrating such patterns in the past (Catanzaro and Ekanem 2004, Cilliers et al. 2013, van Heezik et al. 2013, Clarke and Jenerette 2015).

Ornamental plant richness and the proportion of all plants that were crops differed by gender, with women growing more ornamental plant species and a lower proportion of crop species than men. This result is consistent with previous homegarden studies. For instance, Reyes-García et al. (2010) investigated gendered roles in Spanish homegardens and found that although overall plant richness did not differ depending on gardener gender, overall plant species density and species richness of both ornamental and medicinal plants was higher in homegardens managed by women. Moreover, men may be more likely to cultivate vegetables, even though women are more likely to report benefits from garden-produced food (Dunnett and Qasim 2000). But why do women plant more ornamentals? As described by Taylor et al. (2017), women may see themselves as "lifestyle" gardeners focused on plant and flower diversity and beauty whereas male gardeners see themselves as farmers. This argument suggests that interpretations of one's own role as a gardener strongly influences plant richness in gardens. Gender may also influence the way people interact with urban green spaces and the health benefits derived (Richardson and Mitchell 2010). For example, the interaction between green space use and self-reported health suggests that the social environment provided by gardens is more important for women's health, whereas individual socioeconomic status is more important for men's health (Poortinga et al. 2007). One study examining gender in urban agriculture noted that although both men and women engaged with urban agriculture for the same reasons, women receive an additional benefit of stress relief from participating in the gardens (Robertson 2013). Urban gardening can promote relief from acute stress (Van Den Berg and Custers 2011) and women gardeners may come for the restorative qualities above and beyond the food production potential. The cultivation of ornamental species versus crop species is potentially representative of a different type of garden use where gardening is practiced by women as a health or recreational activity. There is also a large literature about gender differences in environmental consciousness with women typically more likely to participate in environmental activities at the household scale (e.g., Hunter et al. 2004). Although it is not clear if these activities extend to urban gardening, increased knowledge about environmental stressors on agriculture can lead to gender differences in changes in farm management (Lovell 2017). In the garden context, increased use of ornamentals by women could thus potentially stem from higher environmental consciousness about, for instance, pollinator loss and their importance for ecosystem services or greater agroecological knowledge about companion planting for pest control. These gendered differences in urban garden plant selection is an area of research that deserves further study.

We found that gardener region of national origin drove differences in crop and ornamental plant richness and total plant and crop (but not ornamental) plant composition. European gardeners planted more crop species than Middle East-origin and USA/Canada-origin gardeners, Asia/Pacific Island-origin gardeners planted fewer ornamental species than USA/Canada-origin gardeners, and Asia/Pacific Island-origin gardeners planted a higher proportion of crop species compared with Latin America-origin and USA/Canada-origin gardeners. These results largely indicate that Asia/Pacific-origin gardeners are more focused on crop production and that USA/Canada-origin gardeners especially, but also Latin America-origin gardeners are relatively more focused on ornamental production. These results are corroborated by a recent study in homegardens in Chicago that found that Chinese-origin gardeners had lower ornamental plant richness compared with Mexican-origin and primarily USA-born African American gardeners (Taylor et al. 2017). Several previous studies document differences in especially crop and medicinal plant composition depending on culture, which may be strongly tied to national origin. For instance, gardeners, especially immigrant gardeners, frequently plant crops and medicinal plants representative of their traditional foodways and cultures because these plants provide a connection to place of origin or their homelands (Corlett et al. 2003, Taylor and Lovell 2015, Taylor et al. 2017). These differences can lead to significant differences in crop species composition among different immigrant groups (Taylor et al. 2017), as found in this study. At the extreme case, attention to unique crops and foodways may even lead to discovery of new cultivated species within urban garden plots (Taylor and Mione 2019). In Toledo, Ohio, Burdine and Taylor (2018) found that cultural desirability of a crop plant was the most important factor (more important than availability of seed, ease of growing, caloric or nutritional value, or amount of space that crop used) for determining which crops were grown in gardens. Thus it is clear from gardens in several geographic areas across the United States, e.g., in states such as California, Illinois, and Ohio, that national origin, immigrant status, and cultural foodways may strongly influence plant choice for cultivated species thus influencing plant species richness and composition in different gardeners' plots. Because allotment gardens may host individual gardeners from many regional, cultural, and socio-demographic backgrounds, documented differences in plant composition among different socio-demographic groups may scale up to enhance agrobiodiversity at the scale of the garden, with positive implications for ecosystem service providers. Although in many cases culture and national origin may strongly drive planting choices, gardeners may not always have success.

Changes in temperature and extreme conditions may put ecological constraints on traditional crops that migrants wish to grow, while at the same time, other activities, such as growing donated crop plants, not necessarily traditional to gardener culture, e.g., kale grown by Mexican and Salvadoran gardeners, may lower plant diversity among socio-demographic groups (Glowa et al. 2019).

In support of our second prediction, we found that time spent in the garden positively related to plant and crop richness and also strongly influenced plant and crop composition. Gardeners often spend more time in the garden to socialize with family members and neighbors (Gray et al. 2014), and labor capital associated with gardening with family members or friends may allow gardeners to cultivate and more intensively care for more species or a different mix of species. Even though temperature extremes may potentially have strong influences on plant species survival within gardens, with enough motivation and time spent caring for chosen crop species, gardeners may be able to maintain more plants (Egerer et al. 2019*a*). Among those surveyed, those with less formal education (no more than high school) spent about twice as much time (~10 hours per week) gardening compared to those with more formal education (at least some posthigh school education, ~5 hours per week), were more likely to be employed in agriculture and service industries, typically lower paying jobs, and were more often motivated by recreation and health, and not food production (Appendix 2). All of these factors may have influenced plant choice and the number of plant species grown. However, despite previous suggestions that low-income gardeners with less food access are more motivated by food (Clarke et al. 2014), gardeners in our survey with less education (and therefore likely lower incomes) did not tend to grow more or a higher proportion of crop species. Interestingly, age influenced total plant composition, as well as crop composition, as did the amount of time spent in the garden (Figs. 2, 3). Among gardeners surveyed, 45% were over 60 years old, with many already retired. The apparent differences in how age and hours spent gardening might be a trade-off between labor and knowledge capital. Older gardeners tended to have more years of gardening experience, and may not require as much time to grow the plants they choose. Moreover, younger gardeners (22–50) tend to spend less time in gardens and were mostly motivated by food (Appendix 2). Gardeners in this age range are often raising young children and becoming responsible for caring for aging parents, so these gardeners may have high food needs, but less time to garden. So time gardening and plant selection may also be influenced by household responsibilities, including acquiring income, and child and parent care.

Finally, we found that plant composition differed depending on gardener motivations, but not in the way we had predicted. We documented that food, recreation, nature connection, health, and social reasons, e.g., friends and family, were the most important motivations mentioned by gardeners, consistent with other studies mainly conducted in the United States, Europe, and Australia (Čepić and Tomićević-Dubljević 2017, Egerer et al. 2019*b*). But why should differences in primary motivations spur differences in plants grown? We predicted that gardeners motivated by food would grow more crop species as well as a higher proportion of crop plants, but we did not find support for this prediction. However, we did find that gardeners motivated by nature connection had more dissimilar plant composition from one another compared with other groups, likely because of their inherent interest in "watching plants grow." Several gardeners mentioned to us that they garden to see a wide diversity of plants, and enjoy sharing the garden space with a diverse mix of plant species. On the other hand, gardeners motivated by recreation and food tended to grow similar plants to others with the same primary motivation for gardening. One might assume that those gardeners motivated by food, and in particular by increasing their food security or access would tend to grow more crops, and especially crops that produce more food, and fewer ornamental plants. Accordingly, the urban gardening literature is filled with theoretical and empirical evidence of how wealthier gardeners with more access to education, income, and plants have higher plant diversity, especially of ornamental crops in their plots, and in contrast low income gardeners are more concentrated on food crops (Catanzaro and Ekanem 2004, Cilliers et al. 2013, van Heezik et al. 2013, Clarke and Jenerette 2015). However, we did not find differences in plant, crop, or ornamental richness or in proportion of crop plants grown depending on gardener motivations. In at least one other study, the most economically disadvantaged gardeners planted a high diversity of ornamental flowering plants (Taylor and Lovell 2015).

CONCLUSION

In this study, we document that several gardener socio-demographic factors influenced plant richness and composition, but the specific factors differed depending on plant identity (crop, ornamental) and community characteristics (proportion of crop species, richness, and composition). Understanding the various drivers of plant diversity and composition in gardens is critical, as gardens with higher local plant species richness, including of crops, ornamentals, and weeds, can support higher pollination, pest control, and climate regulation services, and may also boost crop production and support other aspects of human well-being (Lin et al. 2015, Egerer et al. 2019*a*). In particular, our results indicate that gardens with more female gardeners may be able to better support insect pollinators or natural enemies, given the higher richness of ornamental plants cultivated. Nevertheless, although plant species richness is often construed as inherently positive, the majority of crop and ornamental plants in gardens are often not native to the region where currently cultivated (e.g., Taylor and Lovell 2015), and presence of non-native species can sometimes negatively impact associated biodiversity (e.g., Matteson et al. 2008). Thus understanding more about how socio-demographic factors affect floral availability and thus beneficial insects that provide ecosystem services is warranted (e.g., Iuliano et al. 2017). Our results may also suggest that gardens with more gardeners motivated by nature connection and with socio-demographically diverse gardeners, e.g., differing in national origin, age, and free time spent gardening, may support higher species richness, and higher dissimilarity in crop composition in different plots. Thus ensuring garden access to individuals from a wide range of socio-demographic backgrounds may be one key recommendation for increasing plant richness and associated ecosystem functions in urban gardens. This could be accomplished either by city government support and maintenance of individual gardens accessed by a socio-demographically diverse group of gardeners, or by supporting a network of gardens across a larger urban landscape, each of which may cater to a

smaller subset of a city's socio-demographic diversity. Important next steps will be to identify how differences among gardeners in allotment plots in a community garden scale up to influence plant diversity at the scale of the entire garden, and how changes in garden plant richness or composition affects food production, as well as abundance, richness, foraging behavior, and interactions among beneficial insects such as pollinators or natural enemies of pests that visit gardens.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/11666

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Data Availability:

The data/code that support the findings of this study are openly available in Dryad at https://doi.org/10.7291/D1Q085.

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Appendix 1. Gardener Survey

Through this survey, we would like to know more about your interest in participating in a community garden, your gardening techniques, your diet, your access to varied food, and basic demographic features. We are aware that some information in this survey may be sensitive, and we want to assure you that all information you provide will remain completely confidential and will be used exclusively for the purpose of this study. This survey is completely voluntary; please feel free to skip any questions or to stop at any time. Thank you for your time!

1. Garden Name: _____

2. Date: _____

3. Age: _____

4. How many family members do you live with?

o 0 o 1-3 o 4-6 o 7-1 o 10+

5. How many other people do you live with?

o 0 o 1-3 o 4-6 o 7-1 o 10+

6. How many people in your family (including you) are?:
   o Women over 18
   o Men over 18
   o Girls 0-18 years old
   o Boys 0-18 years old

7. What is your gender?
   o Male
   o Female

8. What is the ethnicity of your family (mark all that apply)?:
   o White
   o Hispanic or Latino
   o Black or African American
   o Native American or American Indian
   o Asian/Pacific Islander
   o Other

9. What is the national origin of you or your parents, if not U.S.A.?

10. Is there a language other than English spoken at your home?:
    o Yes
    o No

If so, what language(s)?: _____

11. How far away do you live from the garden?:
- o <1 mile
- o 1-5 miles
- o 10 miles
- o >10 miles

12. What are the primary sources of employment for you and other members of your immediate family (mark all that apply)?:

o Agriculture
o Gardening
o Construction
o Sales
o Domestic Service
o Education
o Legal Services
o Health Services
o Office Administration
o Technological Services
o Restaurant/Food Service
o Other _____(employment type)

13. What is the average annual income earned in your immediate family?:

o $0-$10,000	o $10,000-$19,999
o $20,000-$29,999	o $30,000-$39,999
o $40,000-$49,000	o $50,000-$74,999
o $75,000+	o I'd rather not say

14. What is your highest level of completed education?
o No formal schooling
o Elementary school
o Middle school
o Some high school
o High school graduate
o Trade/technical/vocational training
o Some college
o Associate degree
o Bachelor's degree
o Master's degree
o Professional degree
o Doctorate degree

15. How long have you been gardening?
____ years

16. List the top reasons why you garden?
A. _____
B. _____
C. _____

17. How many hours per week do you spend at this garden?

18. Which crops do you grow in your garden?

o Tomato	o Tomatillo	o Beans	o Corn	o Amaranth	o Artichoke
o Arugula	o Asparagus	o Beet	o Bitter melon	o Broccoli	o Cabbage
o Carrot	o Cucumber	o Eggplant	o Kale	o Leek	o Lettuce
o Mustard	o Parsnip	o Peppers	o Potato	o Squash	o Chard
o Basil	o Dill	o Cilantro	o Oregano	o Garlic	o Thyme
o Mint	o Lavender	o Strawberry			

List other crops you grow:
_____

19. Which flowers or ornamentals do you grow in your garden?

o Dahlia	o Borage	o Iris	o Calendula
o Nasturtium	o Sunflower	o Zinnia	o Cosmos
o Rose			

List other ornamentals you grow:
_____

20. Do you have problems with pests or diseases in your garden?
o Yes
o No
o Don't know

If yes, which of the following methods do you use to protect your crops from pests or diseases (mark all that apply)?

o Hand remove pests
o Organic, purchased sprays
o Homemade sprays
o Pesticides
o Release ladybugs
o Other:_____

21. Do you add any soil amendments in your garden?
o Yes
o No

If so, what do you add?
o Fertilizer o Compost
o Manure o Worm castings
o Blood meal o Cover crop
o Mulch o Other _____

22. Where do you get soil amendments you add (mark all that apply)?:
o Purchase o From other gardeners
o Garden management o Make it yourself o Other_____

23. Who taught you how to garden or farm?
o Family member o Friend
o Self-taught o Workshop/Class
o Other gardeners o Other

24. How many pounds of fruits, vegetables, and herbs to you harvest from your garden every week during summer (May-October)?
o 0 lbs
o 1-5 lbs
o 6-10 lbs
o 11-20 lbs
o 20 lbs+
o Don't know

The next six questions are standard questions developed by the U.S. Department of Agriculture.

The following are several statements that people have made about their food situation. For these statements, please indicate whether the statement was often true, sometimes true, or never true (for you/your household) in the last 12 months:

25. "The food that (I/we) bought just didn't last, and (I/we) didn't have money to get more."
o Often true o Sometimes true o Never true o Don't know

26. "(I/we) couldn't afford to eat balanced meals"
o Often true o Sometimes true o Never true o Don't know

27. In the last 12 months, since last (name of current month), did (you/ or other adults in your household) ever cut the size of your meals or skip meals because there wasn't enough money for food?
o Yes o No o Don't know

If so, how often did this happen?
o Almost every month
o Some months but not every month
o Only for 1 or 2 months
o Don't know

28. In the last 12 months, did you ever eat less than you felt you should because there wasn't enough money for food?
o Yes o No o Don't know

29. In the last 12 months, were you ever hungry but didn't eat because there wasn't enough money for food?
o Yes o No o Don't know

30. Has a doctor ever told you that you are at risk or have any of the following?:
o Diabetes
o Cancer
o Asthma
o Cardiac Disease
o Hypertension
o Obesity
o Other persistent health problems

31. Has gardening had a positive impact on you or your family's well-being?
o Yes
o No

If so, how?
_____
_____
_____

Thank you for your participation!

Appendix 2. Relationships between socio-demographic factors of gardeners.

METHODS

To examine potential interactions between socio-demographic variables (e.g., gender, age, region of national origin), motivations for gardening, and gardening experience (e.g., hours spent in the garden) examined in this study, we used chi-square analysis with the CHITEST function in Excel. For each variable, we examined axes of difference for other variables. Age and hours spent gardening were continuous variables, so we first grouped these into categories. For age, we grouped gardeners in three groups each representing close to a third of gardeners: 22-50 years old (n=53), 51-62 years old (n=52), and >63 years old (n=61). For hours spent in the garden, we grouped gardeners in three groups each representing close to a third of gardeners: 0.5-3 hours (n=55), 3.5-6 hours (n=56), 6.5-60 hours (n=55).

RESULTS

There were several differences in other socio-demographic features with gardener gender (Fig. A2.1). Gardener gender was consistent across different age groups ($P=0.325$), but education ($P<0.001$), motivations ($P=0.004$), region of national origin ($P=0.001$), and hours spent in the garden ($P=0.031$) all differed between men and women. Women were more highly educated than men, tended to be more highly motivated by nature connection and less by health, recreation, and social reasons, and spent fewer hours gardening compared with men. In addition, there were more female Asia/Pacific-origin and Europe-origin gardeners compared with males.

Only region of national origin differed depending on gardener age (Fig. A2.2). Gardener age groups were balanced between gender ($P=0.245$), education ($P=0.261$), motivations ($P=0.430$), and hours spent gardening ($P=0.348$), but there were differences in age groups with region of national origin ($P=0.017$). There were more older gardeners from Europe and USA/Canada and more gardeners from younger age groups from Asia/Pacific Islands and Latin America.

Education level differed with all other socio-demographic, motivation, and experience factors (Fig. A2.3). Gardener education level differed with age ($P<0.001$), gender ($P<0.001$), region of national origin ($P<0.001$), motivations ($P<0.001$), and hours spent gardening ($P<0.001$). Older gardeners were more likely to have no formal education or to have graduate degrees and intermediate age gardeners (51-62) were more likely to have less than high school education. Female gardeners were more likely to be more highly educated. Latin America-origin gardeners were the least educated in the survey group and USA/Canada-origin gardeners were more educated. Gardeners with less education were more likely to garden for recreation and gardeners with more education were more likely to garden for nature connection and social reasons.

All factors differed with gardener region of origin (Fig. A2.4). Gardeners from Latin America and the Middle East were more often male ($P<0.001$). Asia/Pacific-origin gardeners were less likely from the older age group and Middle East-origin gardeners were either from the younger or older age group, missing the intermediate age group ($P<0.001$). Gardeners from Latin America were less educated than other groups ($P<0.001$). Gardeners from Latin America and the Middle East were more likely motivated by recreation and those from USA/Canada, Asia/Pacific

and Europe were more motivated by nature connection ($P<0.001$). Middle East-origin gardeners were more likely to spend long hours in the garden ($P<0.001$).

Motivations of gardeners strongly depended on all other demographic factors and experience (Fig. A2.5). Gardener motivations differed with gardener gender ($P<0.001$), age ($P<0.001$), education ($P<0.001$), region of national origin ($P<0.001$), and hours spent gardening ($P<0.001$). Older gardeners were more motivated by recreation and nature connection while younger gardeners were more motivated by food. Female gardeners were more motivated by nature connection and male gardeners were more motivated by recreation and health reasons. Latin America-origin and Middle East-origin gardeners were more motivated by recreation and Asia/Pacific-origin, Europe-origin, and USA/Canada-origin gardeners were more motivated by nature connection. Gardeners without any formal education were far more likely to be motivated by recreation and less by food compared to all other groups, and gardeners with higher levels of education were more likely to be motivated by nature connection. Finally, gardeners that spent more time gardening (6.5-60 hours per week) were more motivated by recreation than other groups.

The number of hours spent gardening depended on gender, education, and age but not other variables (Fig. A.2.6). The number of hours spent gardening was similar depending on region of national origin ($P=0.522$) and motivation ($P=0.674$). More men spent long hours gardening ($P=0.037$), gardeners with less education spent more time in the garden ($P<0.001$), and older gardeners spent more time gardening ($P<0.001$).

Figure A2.1. Relationships between gender and age, education, region of national origin, motivation for gardening, and hours spent in the garden.

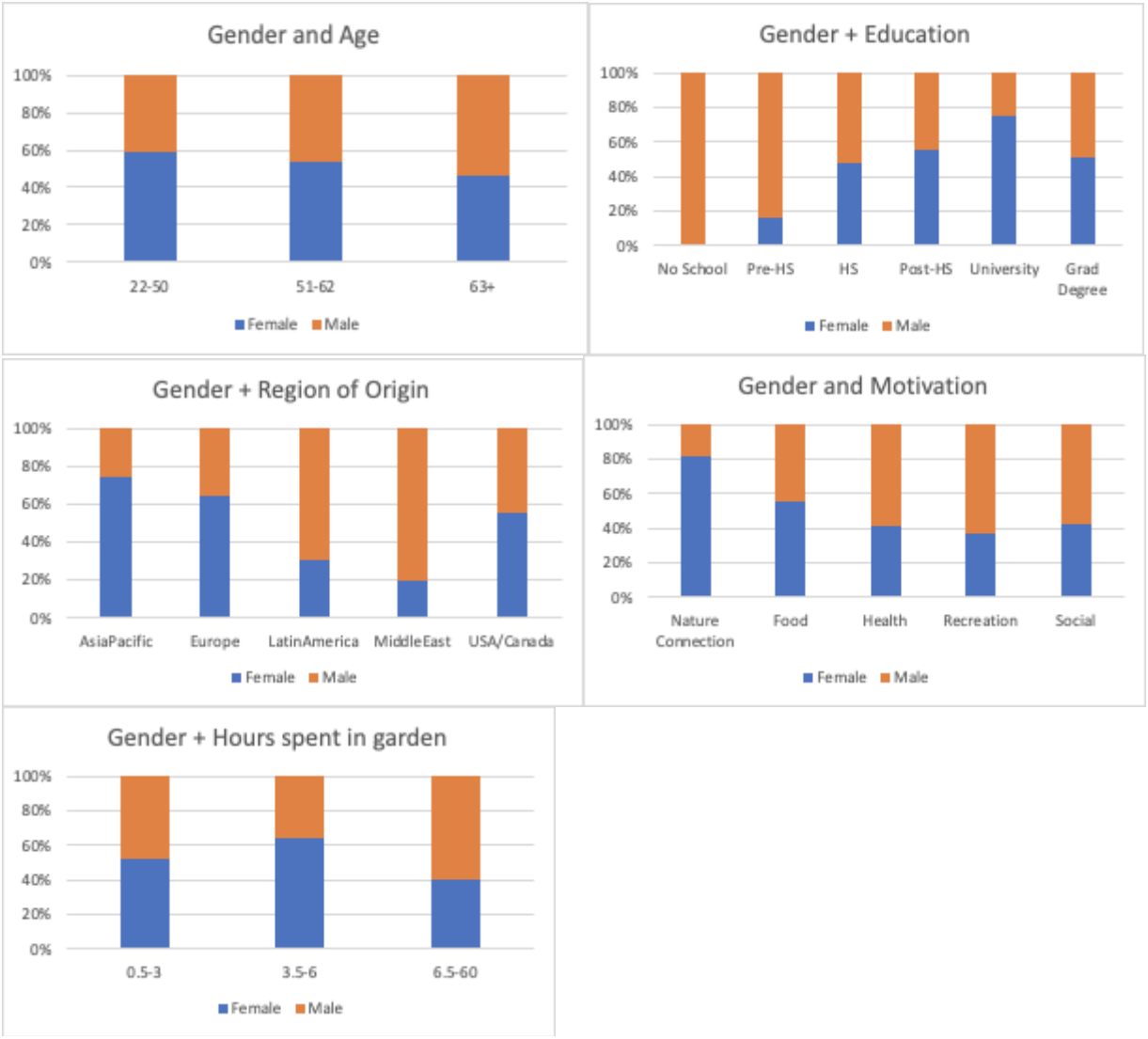

Figure A2.2. Relationships between age of gardener and gender, education, region of national origin, motivations, and hours spent gardening.

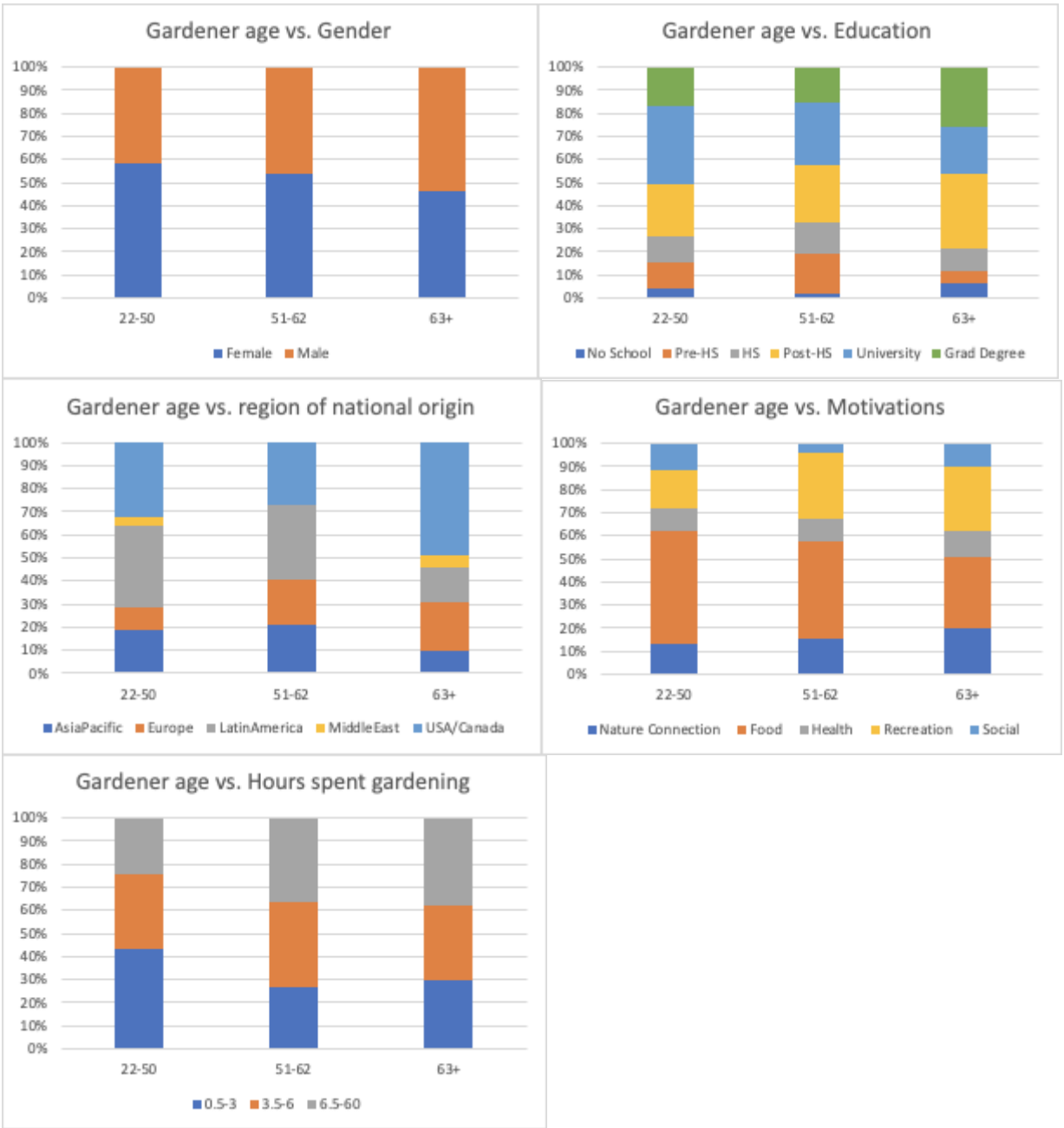

Figure A2.3. Relationships between education, age, gender, region of national origin, motivations for gardening, and hours spent gardening.

Figure A2.4. Relationships between region of national origin and gender, age, education, motivations for gardening, and hours spent gardening.

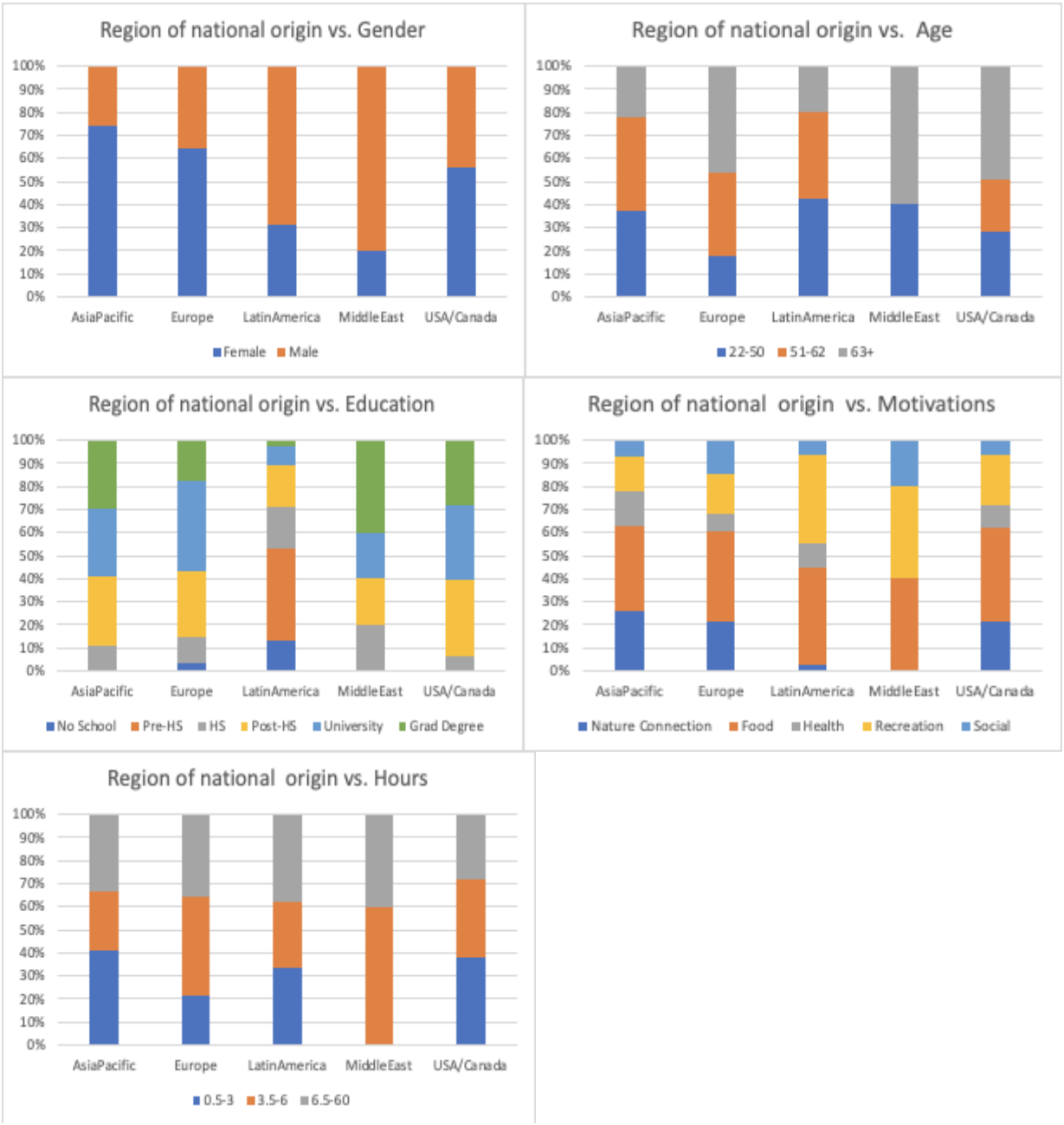

Figure A2.5. Relationships between motivations for gardening and gender, age, region of national origin, education, and hours spent gardening.

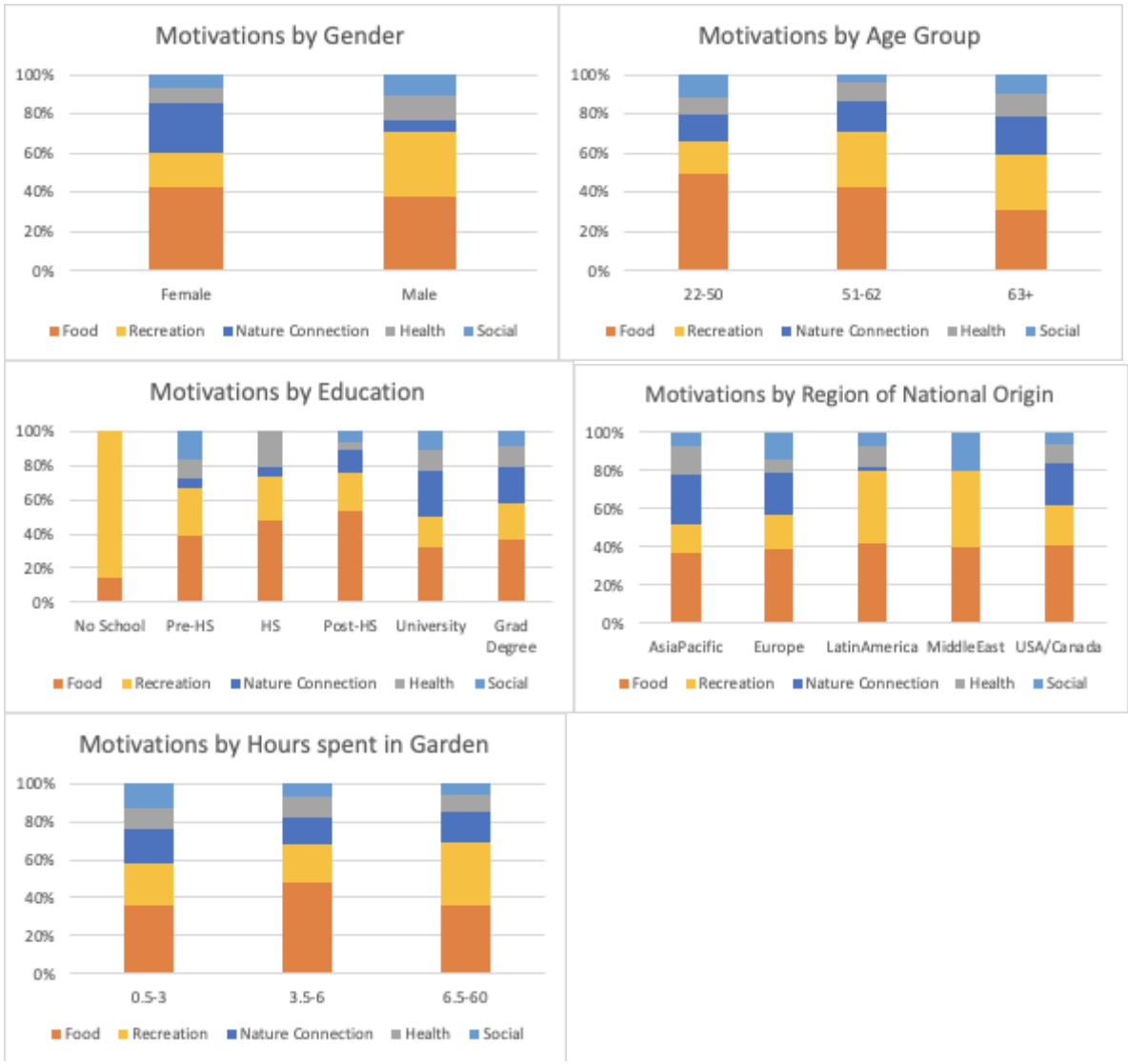

Figure A2.6. Relationships between hours spent gardening and gardener age, gender, education, region of national origin, and motivations for gardening.

Appendix 3. Additional statistical results from generalized linear mixed models.

The following tables show full model results for generalized linear mixed models (GLMM) examining the influences of age, gender, region, education, years of gardening experience, hours spent in the garden, and motivations of gardeners on total, crop, and ornamental plant species richness and proportion of plants that were crops.

Table A3.1. Results of GLMM model selection for models examining relationships between gardener socio-demographic factors, gardening experience, and motivations for gardening and plant species richness, crop species richness, and ornamental plant species richness. All models within two AIC points of the top model are shown and were included in average models. Garden was included as a random effect for all models. A plus (+) indicates a factor was included in that model, NA indicates the factor was not included in that model.

Model	Age	Gender	Region	Edu-cation	Years	Hours	Moti-vation	df	AICc	Delta AIC
Total Plant species richness (LN)										
1	NA	NA	NA	NA	NA	0.144	NA	4	271.4	0.00
2	NA	NA	NA	NA	NA	NA	NA	3	272.3	0.85
Crop species richness										
1	NA	NA	+	+	NA	1.92	+	17	1043.9	0.00
2	NA	+	+	+	NA	1.94	+	18	1044.1	0.22
Ornamental species richness (LN)										
1	NA	+	NA	NA	NA	NA	NA	4	713.8	0.00
2	NA	+	NA	NA	NA	0.347	NA	5	714.3	0.54
3	NA	+	+	NA	NA	NA	+	8	714.5	0.78
4	NA	+	+	NA	NA	0.356	+	9	715.1	1.32
Prop. of species that were crop species										
1	NA	+	+	NA	NA	NA	NA	7	513.9	0.00
2	+	+	+	NA	NA	NA	NA	8	514.5	0.64
3	NA	+	NA	NA	NA	NA	NA	3	515.0	1.16
4	NA	+	NA	NA	+	NA	NA	4	515.1	1.20
5	+	+	NA	NA	NA	NA	NA	4	515.2	1.29
6	NA	+	+	NA	+	NA	NA	8	515.2	1.36

Table A3.2. GLMM model results for tests examining how gardener socio-demographic variables influence plant, crop and ornamental richness reported by gardeners as well as the proportion of plant species that were crops in urban gardens in the California central coast. All models results are for averaged models. Pairwise results for factors with multiple levels are reported in Tables A3.3-A3.7.

Dependent variable	Factors in best model	No. of best models factor was included	z	p
All plant species richness	LN Hours	1	2.729	0.006
Crop species richness	Education	2	*Table A3.3*	*Table A3.3*
	LN Hours	2	3.16	0.002
	Motivation	2	*Table A3.4*	*Table A3.4*
	Region	2	*Table A3.5*	*Table A3.5*
	Gender	1	0.61	0.542
Ornamental species richness	Gender	4	2.393	0.017
	LN Hours	2	1.721	0.085
	Region	1	*Table A3.6*	*Table A3.6*
Prop. of plants species that were crops	Gender	6	2.53	0.011
	Region	3	*Table A3.7*	*Table A3.7*
	Age	2	1.306	0.192
	Years	2	1.155	0.248

Table A3.3. GLMM model results for pairwise comparisons examining differences in crop plant richness based on education level of gardeners. Numbers show p-values for pairwise comparisons of different levels for reach factor.

	High School	No School	Post-High School	Pre-High School	University
Graduate degree	0.264	0.767	0.995	0.993	0.938
High School		0.512	0.751	0.812	0.709
No School			0.384	0.387	0.375
Post-High School				0.995	0.929
Pre-High School					0.954

Table A3.4. GLMM model results for pairwise comparisons examining differences in crop plant richness based on motivations of gardeners. Numbers show p-values for pairwise comparisons of different levels for reach factor.

	Food	Health	Recreation	Social
Nature Connection	0.296	0.507	0.341	0.57
Food		0.090	0.976	0.146
Health			0.119	0.957
Recreation				0.169

Table A3.5. GLMM model results for pairwise comparisons examining differences in crop plant richness based on region of national origin. Numbers show p-values for pairwise comparisons of different levels for reach factor.

	Europe	Latin America	Middle East	USA/Canada
Asia/Pacific Islands	0.092	0.645	0.162	0.808
Europe		0.29	0.019	0.026
Latin America			0.099	0.462
Middle East				0.175

Table A3.6. GLMM model results for pairwise comparisons examining differences in ornamental plant richness based on region of national origin of gardeners. Numbers show p-values for pairwise comparisons of different levels for reach factor.

	Europe	Latin America	Middle East	North America
Asia/Pacific	0.072	0.083	0.678	0.033
Europe		0.939	0.568	0.959
Latin America			0.549	0.967
Middle East				0.5312

Table A3.7. GLMM model results for pairwise comparisons examining differences in the proportion of all plants that were crops based on region of national origin of gardeners. Numbers show p-values for pairwise comparisons of different levels for reach factor.

	Europe	Latin America	Middle East	North America
Asia/Pacific	0.1127	0.025	0.636	0.006
Europe		0.347	0.849	0.1712
Latin America			0.587	0.887
Middle East				0.546