Urban Ecosyst (2017) 20:51–63
DOI 10.1007/s11252-016-0587-4

Floristic composition and richness of urban domestic gardens in three urban socioeconomic stratifications in the city Heredia, Costa Rica

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Published online: 9 August 2016

Abstract The urban domestic gardens that are part of urban green areas have become a very important element due to their ecosystematic benefits and the poor information about them. Information regarding the floristic richness of three socioeconomic stratifications from the city of Heredia, Costa Rica is presented in this study. Research was conducted from October 2011 to May 2012. Information was collected using a semi-structured questionnaire, which was provided to 61 garden owners, including the owner's personal data, time living in the dwelling, area of the property and the garden, variation of its size in time and the garden's location on the property. In addition, a floristic inventory was conducted in each garden as well as a taxonomic identification of all plants. Vegetative forms and substrates were also noted. Characteristics of the gardens and their owners were then analyzed to determine the relationship of species richness between the three sites studied. The number of plant species recorded was 618, corresponding to 102 families (19 % exotic). Regarding geographical origin, 64, 4 % were exotic, 35,6 % native. Orchidaceae (93 spp.) and Araceae (39 spp.) were the most dominant families. The variables of garden area and location and owner's age determined the garden's floristic richness. In addition, *the garden's area and vegetative forms varied among the sites studied probably due to socioeconomic differences among them.* Diversity of pioneer plants increased with the garden's area. In sum, this research provides important floristic information of domestic gardens, since, being private property, data about them is scarce and municipal management guidelines are nonexistent.

Keywords Urban gardens · Floristic composition · Urban ecology · Costa Rica

Introduction

Urban growth is occurring rapidly. In 2008, around 50 % of the world's human population inhabited urban environments. Such urban development is faster in developing countries where 80 % of the urban population is predicted to be concentrated by 2030 (Goddard et al. 2010).

The previous information implies the need for proposed precautionary measures. Singh (2010) points out that political instruments and scientific evidence emphasize the need to establish green areas that take into consideration ecological-social aspects within the urban system to improve the well-being of city dwellers. Atiqul (2011) defines these areas as those public and private spaces located in urban regions covered by vegetation that are directly or indirectly available to their users.

Loram et al. (2011) state that these green areas in the city cover a wide range of complexity and morphology. All are important for different reasons: 1) they form a substantial proportion of the green urban area; 2) they contribute to the maintenance and improvement of urban biodiversity; 3) they provide benefits to human health and welfare; and 4) they draw city dwellers closer to nature.

Moreover, Cameron et al. (2012) point out the positive role of the green urban infrastructure as a supplier of ecosystem services. This function embraces green public areas and

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private spaces such as domestic gardens. They are defined as artificial spaces organized and structured according to the objectives of the owners. This space is considered an extension of the dwelling, where personal activities such as relaxation, leisure or recreation and agricultural activities occur (Meza 2009).

In Costa Rica, as well as in other parts of the world, research on floristic composition of private domestic gardens in urban areas is meager. There are some recent studies about this topic in the United Kingdom (Thompson et al. 2004; Smith et al. 2005, 2006), Ecuador (Murray 1997), Argentina (Madanes and Faggi 2008), Chile (Meza 2009), and Brazil (Akinnifesi et al. 2010).

Likewise, Jaganmohan et al. (2012) considered these areas as part of the green infrastructure with fewer investigations in cities.

Smith et al. (2006) indicate the need to understand urban flora, since the recognition of the potential value of its contribution to the biodiversity is currently increasing. For example, in the United Kingdom certain initiatives have been implemented for the conservation of species in these urban systems but have been a limited effort due to the lack of information.

It is of importance the connection of these urban domestic spaces with gardening. Saldias (2011) describes it as the art and technique of growing gardens. This activity has captivated human beings throughout history. It expresses, in a natural way, the desire to grow and take care of garden plants for the purpose of creating comfortable and beautiful areas with other objectives such as satisfying food and medicinal necessities.

Based on the above, in order to learn about garden contribution to urban areas, this research attempts to determine the composition and relationships between the plant species richness and predictor variables from private domestic gardens in a three different socioeconomic stratifications in the city of Heredia, Costa Rica.

Materials and methods

The study was conducted in the city of Heredia, located in the Central Valley, which is part of the greater urban area of Costa Rica, called the Great Metropolitan Area (*Gran Área Metropolitana-GAM*).

The city of Heredia, with an area of 3 km^2, has a total population of 19,138 inhabitants (INEC 2015) and a population density of 6379.33 inhabitants/km^2. Its population is 100 % urban and is ranked the third largest city in Costa Rica, preceded by San José and Alajuela.

Its average annual rainfall is 2374.3 mm and the wettest months are September and October with average amounts of 410.88 mm and 424.6 mm, respectively (Romero et al. 2011). The elevation of Heredia is 1150 msnm (La Gaceta 2009).

With respect to the selection of urban domestic gardens, three types of urban socioeconomic stratifications were chosen as follows: mixed (residential and commercial) corresponding to Heredia Urbano; residential, with reference to the neighborhood Residencial María Auxiliadora; and welfare housing development (located in Ciudadela Bernardo Benavides), which is defined as a residence not exceeding a given income as determined by the Bank of Home Mortgage (*Banco Hipotecario de la Vivienda*-BANHVI) in coordination with the Costa Rican Institute of Housing and Urban Planning (*Instituto Nacional de Vivienda y Urbanismo-INVU*) (Palacios 2005). Each socioeconomic stratification was selected in different sites located in specific communities from the city of Heredia (Fig. 1).

Domestic gardens are green areas (including backyards) that are on the perimeter of the property completely surrounded and containing plants grown in soil. This research was conducted only in urban domestic gardens whose owners lived in the property, but did not take into account green areas of apartments and condominiums (González-Ball 2014).

From October 2011 to December 2012, private domestic gardens were identified for each socioeconomic stratification through a stratified sample using Google Earth maps and the ArcGis software. The above information was later corroborated using a GPS to record the position of each garden. Subsequently, using a random table of the SPSS software, 10 % of the total sample was selected for each category.

A total of 61 gardens were studied in three different urban socioeconomic stratifications, similar to another research done by González-Ball 2014. The sample consisted of 35 gardens in Urban Heredia HU (mixed: residential and commercial), 12 María Auxiliadora Residential MA (residential) and 14 in Bernardo Benavides BB (welfare development areas). Using a previously validated semi-structured interview, data was collected including time the owner has lived in the dwelling, area of the property and garden, variation of its size in time and patterns of the garden's location on the property ($N = 61$).

The geographical position and altitude of each dwelling was determined using a GPS (Garmin 60CSx) with a precision of <10 m and the garden area was measured with a tape measure (50 m ± 5.1).

The location of the garden was categorized on the property as follows: 1) in front of the dwelling called ¨*antejardín*¨ in Spanish, 2) back of the dwelling, 3) surrounding the dwelling, 4) back and front of the dwelling, 5) back, front and side of the dwelling, 7) front and one side of the dwelling, 8) side of the dwelling, and 9) side and back of the dwelling.

Fig. 1 Location of urban domestic gardens in three sites of the research areas: Bernardo Benavides, Residencial María Auxiliadora and Heredia Urbano, Heredia, Costa Rica

The plant collection growing in soil, pots, and hanging baskets as well as the ones that grew by natural succession were identified in each garden.

When the plant could not be identified in situ, a picture or a sample was taken for later identification at the National Herbarium of the National Museum of Costa Rica. Floral guides were also used (Byrd 1982; Hammel 1999; Lee 2009; Morales 2000; Whistler 2000; Estrada and Rodríguez 2009), in addition to data bases from the web such as Atta 2001, w3tropicos 2007, CONABIO 2012, Google 2012 and consultation with plant specialists in ornamental plants, medicinal plants, and ferns.

Each plant species was grouped into the following categories: 1) origin: native, exotic, naturalized and endemic; 2) Substratum (where the plants were planted): soil (directly in soil), pot (containers of different shapes and materials), baskets (wireframe, plastic or rope hanging baskets), raised bed (container of rectangular form made from concrete), trunk (part of a trunk from a tree); 3) plan life-forms such as a large or small tree (<5 m high), bush, epiphyte, herbs, parasite, succulent and climber; 4) pioneer: plants that grew in the garden without human intervention.

The presence of soil coverage was classified by the percentage of cover as follows, 0: lack of a lawn, 1: 25 %, 2: 50 %, 3: 75 %, and 4: almost 100 % lawn cover.

The plants were identified at the level of genus and species and those that could not be fully identified were designated by genus only. Those plant species that consisted of several varieties were identified just at the species level (Smith et al. 2006).

Statistical analysis

To determine if the garden sizes and species richness differed among the three study sites a Generalized Linear Model (GLM) with Gaussian and Poisson distribution was fitted, respectively. To assess the relationship of plant species richness with the characteristics of the gardens (age, area and location in the property) and owners (age, sex and time living on the property) GLMs with Poisson distribution were used. The Minimal Adequate Models were estimated through an iterative stepwise model selection by the Akaike Information Criterion for small sample size (stepAICc). The resultant models explain the highest proportion of variation by using the minimum number of variables. The predictor variables in the final models were tested for multicollinearity using Variance Inflation Factor (VIF). A Quasi-poisson GLM was fitted to correct standard errors in the final models that showed over dispersion. Before fitting

the models, the predictor garden area was log-transformed to homogenize its variance. The models were fitted with native, exotic and pioneer species richness as response variables. Significance of each variable in the resultant models with Poisson and Quasi-poisson distribution were tested using the χ^2 statistic, and F statistic was used in models with Gaussian distribution. Furthermore, a χ^2 test was performed to test for differences in the type of substrate used for planting and vegetative life forms among the three socioeconomic stratifications.

The analyses were conducted using R version 3.1.2.

Table 2 Richness, families and percentage of exotic and native species found in private domestic gardens, Heredia, Costa Rica

Variable	Sites		
	BB	MA	HU
Cumulative absolute richness	463	638	1750
Absolute Richness (minimum and maximum)	15–77	7–103	6–215
Richness per family	67	80	95
Exotic species (%)	63.79	64	62.5
Native species (%)	36.21	36	37.5

Results

A total of 61 garden owners were interviewed, including 50 women (82 %) and 11 men (18 %). Their ages ranged from 21 to 92 years (57.9 ± 14.68) with 31 % of the respondents equal to or older than 65 years. On average, owners' residence time on the property was 35.2 ± 18.36 years. The total garden area surveyed was 5996.29 m^2, ranging between 1.5 m^2 and 1457.68 m^2 (98.3 m ± 228.75). In general, 14.20 % of the total area was associated with BB, 25.30 % with MA, and 20 % with HU. Additionally, the garden area of the three urban land uses was significantly different (Table 1; deviance =12.37, df = 2, p = 0.04).

Some owners indicated that their garden area was reduced in size to build a roof to cover the porch or to add a new room to the dwelling to avoid potential flooding.

The total species richness in the gardens corresponded to 618 species and 79 genera distributed in 102 families, of which 71 belonged to dicotyledonous, 23 to monocotyledonous, 3 to gymnosperms and 5 to Pterydophyta.

Of the total number of plant species in each socioeconomic stratification designation, exotic plants showed the greatest percentage (60 %) while native species were lesser in kind (35 %) (Table 2).

Of the total number of families, 19 % corresponded to exotic species belonging to: Adoxaceae, Aizoaceae, Alstromeriaceae, Asparagaceae, Basellaceae, Buxaceae, Casuarinaceae, Crassulaceae, Cupressaceae, Cycadaceae, Leeaceae, Pandanaceae, Punicaceae, Saxifragaceae, Stretliziaceae, Turneraceae, Violaceae, and Xanthorrhoeaceae, all of which were cultivated. Additionally, 24 cultivated and pioneer species were found in 20 gardens corresponding to 3.5 % of the total (Appendix 1).

Regarding garden soil coverage, 25 were of the native lawn species *Paspalum notatum* (local name *jengibrillo*), 15 were exotic species *Stenotaphrum secundatum* (local name *San Agustín*) and 2 were of the leguminosae family *Arachis pintoi* (local name *manicillo*). From the 61 gardens, the category of garden soil coverage equal to 0 % was found in 21.6 gardens, 25 % in 11, 50 % in 15, 75 % in 8 with almost 100 % soil coverage.

The two most important plant families with respect to their abundance corresponded to Orchidaceae with 93 species, of which 56 % were native and 44 % exotic, and Araceae with 39 species. A total of 23 families were represented by 10 species (Fig. 2). A high percentage of orchids was found in two gardens (HU), with 41 % and 20 % of the total. In addition, 48 species were provided with some level of protection (Appendix 2), the majority of which belonged to the Orchidaceae family.

The number of pioneers by socioeconomic stratification varied from 3 to 13 species in the gardens from BB, 1 to 17 in MA and from 0 to 33 in HU. The owners considered the majority of these plants as weeds, of which 76 % were native.

When the type of substratum was examined (soil, pots, concrete, raised beds, tree trunks and hanging baskets) in the three sites, no significant differences were observed

Table 1 Areas of properties and gardens in the three urban socioeconomic stratifications, Heredia, Costa Rica (±1 standard error)

Socioeconomic stratification	Garden area (m^2)		Property area (m^2)	
	Mean (±)	Range	Mean (±)	Range
BB	21.15 ± 38.46	1.6 – 72.57	142.42 ± 72.05	86 – 182
MA	146.06 ± 65.89	4.39 – 762.16	399.65 ± 77.82	160 – 1028.16
HU	112.79 ± 38.58	1.5 – 1457.68	373.36 ± 45.57	52 – 1657.68

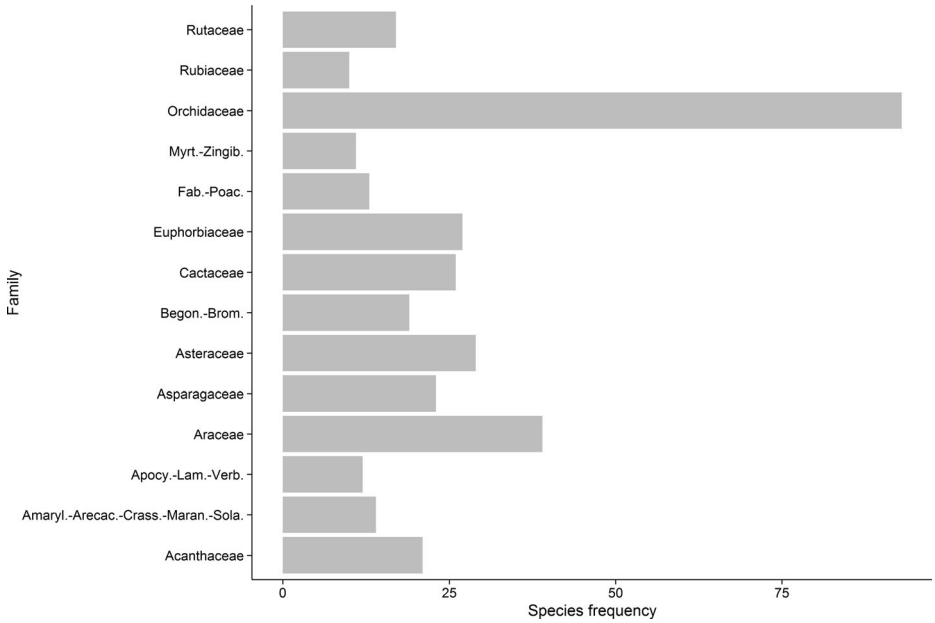

Fig. 2 Plant families most represented in the 61 private domestic gardens sampled, Heredia, Costa Rica

($\chi 2 = 15.30$, gl = 8, $p = 0.05$). Furthermore, it was noted that the use of soil occurred more frequently in the three sites BB, MA and HU, followed by pots (Fig. 3). The categories of hanging baskets, trunks and concrete raised beds, were the least used. Clay tiles, trunks and pots were used to grow orchids. Members of the bromeliaceae family were planted over a trunk or in hanging baskets. The vegetation found on walls or rocks colonized those places naturally.

Herbs, palms, bushes and succulent herbs were cultivated in soil and/or pots, while trees of all sizes were growing directly in the ground (Fig. 4).

The proportions of plant life forms analyzed: (1. herbs, 2. tree (>5 m), 3. small tree, 4. climbers, 5. epiphyte, 6. succulent herbs, 7. palms, and 8. bushes), differed in the three urban socioeconomic stratifications ($\chi 2 = 49.95$, gl = 14, $p < 0.0001$). There was a greater amount of herbs (residual =2.06) and palms (residual =2.86) and a lower amount of succulent herbs (residual = -2.64) and epiphytes (residual = -2.09) in BB. On the other, the MA site had a greater amount of succulent herbs (residual =3.28).

In general, in all three sites herbs were the principal growth form followed by bushes and epiphytes (Fig. 4). Regarding parasitic plants, 8 were members of the Loranthaceaae family. The majority of pioneers belonging to the vegetative form of herbs and epiphytes were represented by Orchidaceae and Bromeliaceae. Climbers were mostly Araceae, Piperaceae and Urticaceae. Succulent herbs belonged to the plant families Asparagaceae, Cactaceae, Crassulaceae, and Euphorbiaceae.

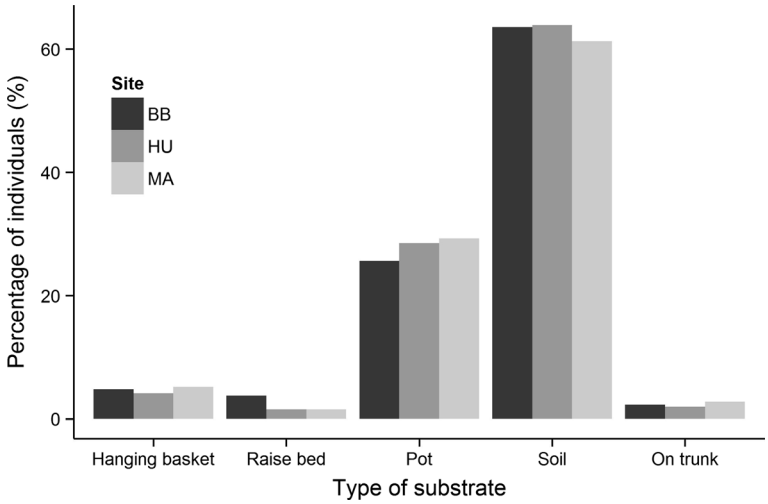

Fig. 3 Types of substrate used by garden owners in the three urban socioeconomic stratifications: Bernardo Benavides, Residencial María Auxiliadora, and Heredia Urbano, Heredia, Costa Rica

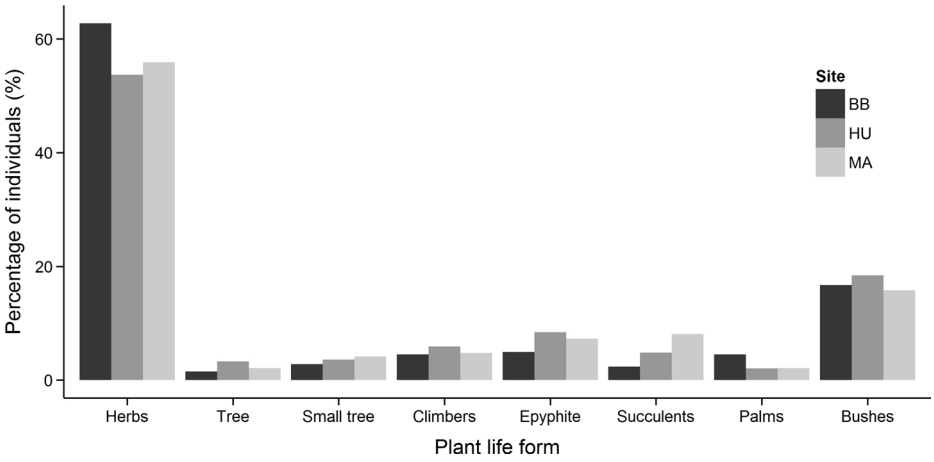

Fig. 4 Plant life forms from the flora studied in the three sites: Bernardo Benavides, Residencial María Auxiliadora and Heredia Urbano, Heredia, Costa Rica

The gardens' area and location in the property were kept in the minimal model that accounted for predictors of garden characteristics, both of which provided a significant reduction of deviance in explaining total species richness ($p < 0.001$). The highest reduction of deviance was the gardens' area followed by their location in the property (Table 3). Species richness had a positive trend with area (Fig. 5), and there were less species of plants in the gardens located in front of the houses compared to other locations (Fig. 6). It was also found that total species richness was significantly higher with older owners (Table 3).

Three predictor variables of garden's characteristics were retained in the minimal model with native (Table 4) and exotic species richness (Table 6), but only the area provided a significant reduction of deviance ($p < 0.001$) with a positive coefficient value. The garden's location was ranked as the second most important predictor in both models. In relation to owners' characteristics, the predictor age caused significant reduction in deviance ($p < 0.05$) in both minimal models (Tables 4 and 5).

In relation to pioneer species, only the garden's area caused a significant reduction in deviance in the minimal model (Table 6). Richness increased significantly as the garden's area increased (Fig. 7). No significant reduction in deviance was found with the variables retained in the minimal model with owner's characteristics (Table 6).

Discussion

In a country like Costa Rica, with a well-known and internationally recognized environmental policy and approximately 26 % of the national territory under some protection status (Obando 2007), it is antagonistic to learn that there are major environmental problems in Costa Rican cities. For example, most of the sewage generated by human settlements is not treated; solid waste is not classified, treated or recycled; air is polluted with high concentrations of sulfur dioxide, carbon monoxide and nitrogen oxides (Piedra-Castro et al. 2013). In addition, green areas are insufficient to meet the needs of the urban population (Piedra-Castro et al. 2013). Hence it is important to research on urban ecology, which ultimately would translate into generating information for decision making processes.

One of the issues that need to be addressed but has very little information in the country is private domestic gardens in the cities. These sites are of great importance in the urban green scene, providing a series of ecosystemic services, such as provisioning (food and medicines), regulating (air purification, temperature, etc), cultural (relaxation, spiritual benefits, etc.), and biodiversity habitat (Loram et al. (2011), Gaston et al. (2005), Breuste and Artmann (2014).

Specifically, private domestic gardens in the city of Heredia share many similarities with other cities in Latin America. For instance, regarding users, there is a marked participation of

Table 3 Summary of the GLM minimal model for the response variable plants species richness

Model	Predictor variable	Coefficient value	df	Deviance reduction	VIF	p (χ^2)
Garden's characteristics	Area	+	1	394.41	1.71	***
	Location in the property		7	99.36	1.71	***
Owner's characteristics	Age	+	1	157.1	-	***

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

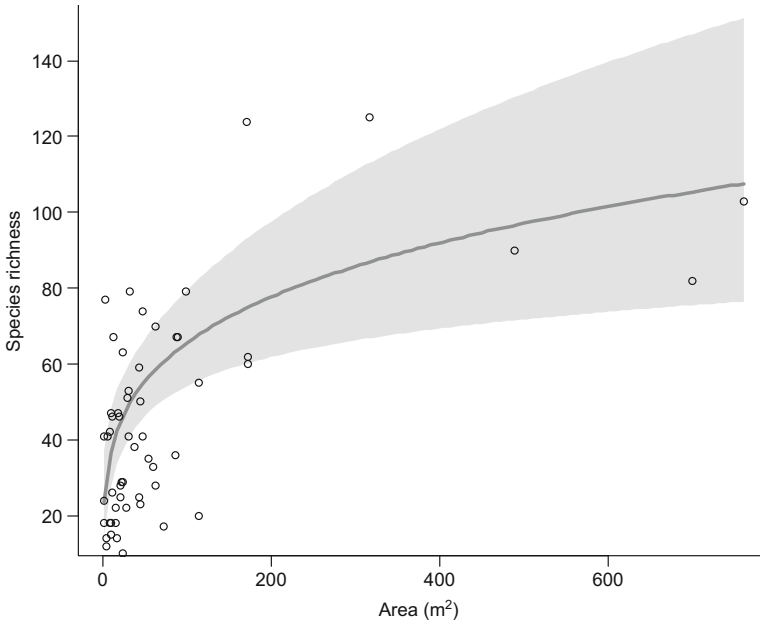

Fig. 5 Species richness response to the predictor garden area of the 61 private domestic gardens, Heredia, Costa Rica

women in gardening activities, which is very similar to what was found in the city of Buenos Aires, Argentina (Madanes and Faggi 2008), in relation to the positive disposition of women towards plants and their need for a green residential atmosphere.

In addition, there is evidence that gardening activities increase with the age of the individual. In the case of the gardens in the city of Heredia, the average age to engage in this activity is 58 years. However, when older (70 years) dedication decreases due to physical problems. As Bhatti (2006) suggests, this activity should be incorporated in policies related to the health and well-being of this age group.

Moving on to the physical and biological aspects of gardens, the wide range of sizes in the city of Heredia is similar to the results reported by Cameron et al. (2012). These authors claim that in cities in the United Kingdom the sizes of green spaces fluctuated between 3.6 m^2 - 2290 m^2, which they attributed to their highly heterogeneous form and function; some may have a few meters of extension but multiple layers of vegetation, while others may have large areas but

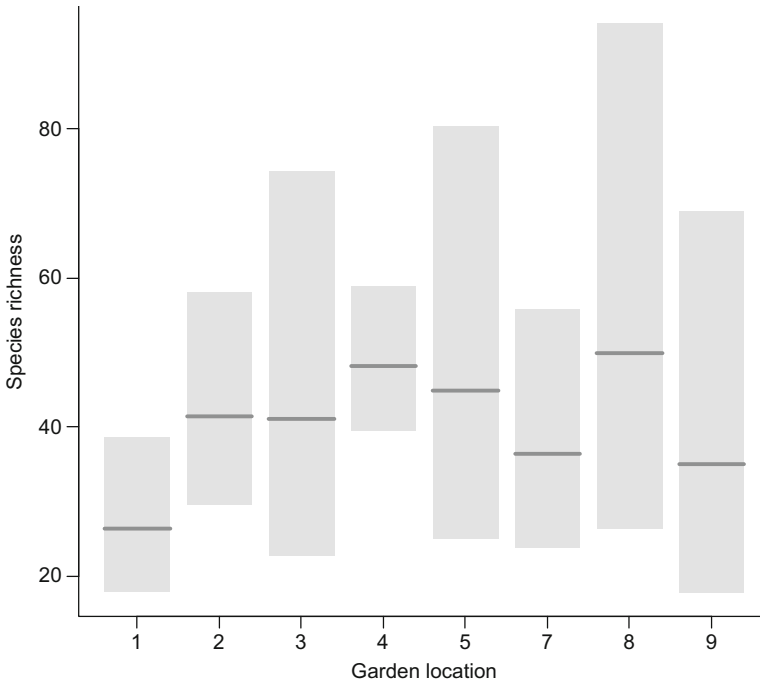

Fig. 6 Species richness response to the location of the garden in the property predictor. 1) front of the dwelling (*antejardín* in Spanish), 2) back of the dwelling, 3) around the house, 4) back and front of the dwelling 5) back, front and side of the dwelling, 7) front and one side of the dwelling 8) side of the dwelling and 9) side and back of the dwelling in the 61 private domestic gardens of Heredia, Costa Rica

Table 4 Summary of the GLM minimal model for the response variable native species richness

Model	Predictor variable	Coefficient value	df	Deviance reduction	VIF	p (χ^2)
Garden's characteristics	Area	+	1	962.90	1.54	***
	Location in the property		7	228.69	1.90	*
	Garden's age	+	1	35.75	1.40	0.13
Owner's characteristics	Age	+	1	191.30	1.17	*
	Sex	+	1	39.21	1.05	0.34
	Time living	+	1	36.00	1.22	0.37

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

lack stratification and have a strong presence of pavement. Meza (2009) also reports similar data for the city of Santiago de Chile, with areas between 8.7 m^2 and 9.499 m^2 but he correlates these differences with the income level of the population and the size of the garden.

In the case of the city of Heredia, garden size variations and the significant differences observed in each site studied (BB, MA, HU) could be related to the socioeconomic stratification established in these districts. This observation is based on two indicators: 1) size of the property indicated in the survey and 2) employment data obtained from the National Institute of Statistics and Census (*INEC*) for each district.

Regarding size, MA and HU properties are 65 % and 62 % larger than BB properties, respectively. These differences in size are related to the origin of the districts. BB was an urban social housing project built by the State of Costa Rica in 1973 (INVU 1973), while MA is a private housing project. HU is the oldest of the three and covers the Metropolitan area of the city, which combines commercial use and services with residential use, having abundant horizontal housing (Marco Ruiz, Municipality of Heredia (personal communication 2012)).

On the subject of occupation, 73 % of BB inhabitants are dedicated to unqualified labor (salespersons, drivers, assemblers, etc.) as opposed to MA and HU, where 87.6 % and 66 % are professionals or technicians (managers, teachers, nurses, etc.), respectively (INEC 2015). Consequently, in lower income areas as the case of BB, it is more difficult for owners to have large gardens, giving priority to more living areas on their properties.

Regarding richness, over 600 species were found in the private domestic gardens of the city of Heredia, which represents a significant contribution to the floristic richness of this Costa Rican urban area. Specifically for this city, 71 tree species had already been reported for the riverfront of the Pirro River that crosses the city (Villalobos et al. 2011), a number much lower than the one provided by the gardens.

Data on the floristic richness of private urban gardens is diverse. Smith et al. (2006c) reported 1166 species in 61 gardens in the United Kingdom, while González-García and Sal (2008) reported 293 species in 96 green private areas in the city of León in Nicaragua. When comparing the latter city with Heredia, differences in richness are found due to the life zone where each one is located. The life zone of the city of León in Nicaragua is Tropical dry forest while the city of Heredia is located in a Premontane forest, which is a favorable climate for a large number of plant species (Montiel 2000).

Despite the great contribution in floristic diversity offered by the private domestic gardens of the city of Heredia, a more detailed analysis reveals a high representation of exotic species. In this respect, Goddard et al. (2010) suggest that the high diversity of flora in gardens may be related to the gardening

Table 5 Summary of the GLM minimal model for the response variable exotic species richness

Model	Predictor variable	Coefficient value	df	Deviance reduction	VIF	p (χ^2)
Garden's characteristics	Area	+	1	386.53	1.56	***
	Location in the property		7	108.45	1.97	*
	Garden's age	+	1	5.45	1.39	0.39
Owner's characteristics	Age	+	1	126.05	1.18	**
	Sex		1	9.65	1.05	0.41
	Time living	+	1	18.50	1.22	0.25

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Table 6 Summary of the GLM minimal model for the response variable pioneer species richness

Model	Predictor variable	Coefficient value	df	Deviance reduction	VIF	p (χ^2)
Garden's characteristics	Area	+	1	125.87	1.07	***
	Garden's age	+	1	4.20	1.07	0.21
Owner's characteristics	Age	+	1	4.06	1.00	0.38
	Sex		1	3.80	1.00	0.39

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

and landscaping business, which promotes the use of exotic plants. In addition, Chacón and Saborío-R (2006) relate the families Asteraceae, Cactaceae, and Arecaceae to a large number of introduced species for ornamental and medicinal purposes. They also mention that information on the population status of exotic flora mostly coming from Tropical Asia and South America is scarce or nonexistent.

ProNativas Network (2010) in Costa Rica and Smith et al. (2005) have expressed their concern about the low diversity of native species and the excess of exotic species in cities. The latter has the potential of invading forests and wildlife areas. In addition, this may be leading to urban biotic homogenization, which poses two problems for conservation: the loss of native species and the consequent homogenization of the biota, as well as the impact of urbanization on human perceptions of nature (McKinney 2006).

However, Knapp et al. (2012) indicate that some exotic species may be providing a positive contribution on the phylogenetic diversity of flora in these areas. In addition, from the point of view of management, a large proportion of exotic specimens may be important sources of fruit, pollen and nectar (Smith et al. 2005).

It is important to emphasize that some species of pioneer flora found have been reported by Gómez and Rivera (1987) in their research on coffee plantation weeds. The city of Heredia reduced the surface occupied by this crop by 23 % between 1989 and 2009 (Romero et al. 2011). However, some of the studied gardens could have been coffee plantations in the past. Given that most pioneer species reported in this research are native, further research must be conducted to determine their contribution to urban ecosystem. Robinson and Lundholm (2012) indicate that this type of vegetation can attract a great diversity of pollinating insects, as well as contribute to their ethnobotanical value.

The presence of higher proportions of herbaceous plants and palms on the BB site indicate the lack of multi stratification in these gardens, which is related to the low average dedicated to green areas (15 %). In addition, the significantly low proportion of epiphytes could be related the economic

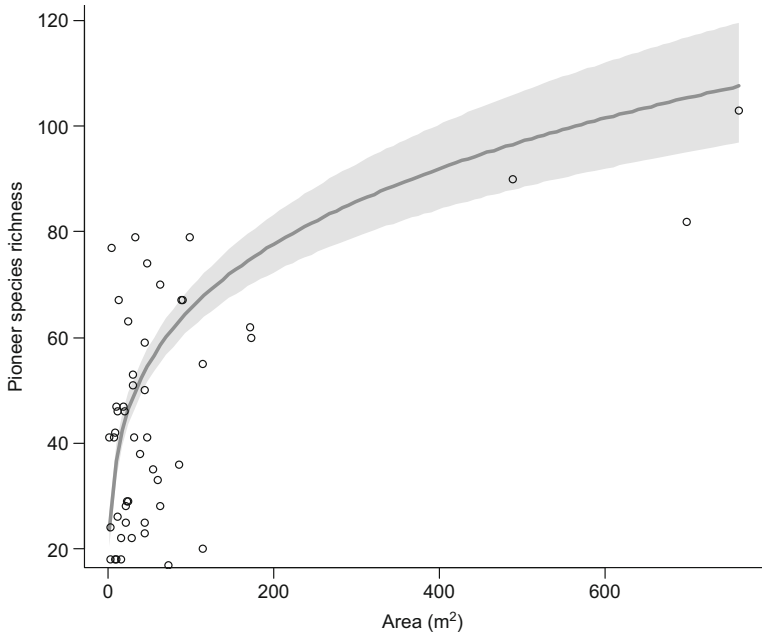

Fig. 7 Pioneer species richness response to the predictor Log garden area of the 61 private domestic gardens sampled, Heredia, Costa Rica

possibilities of the owners of this site; for example, purchasing and maintaining orchids implies a considerable economic cost.

There is little information about the vegetation stratification of urban domestic gardens, although Smith et al. (2005) in the United Kingdom found the following categories: annual, bi-annual/perennial, bush or tree. Similar to this study, the herbs habit had the most exemplars, followed by bushes. This condition could be due to the fact that these are the most common habits for ornamental species preferred by owners of urban gardens.

With respect to the substrate used, most garden owners tend to plant in the ground, mostly because it is more economical. The second method most widely used is pots. Periplo (1999) mentions that the use of containers (pots) in the tropics is a common practice, since plants are easier to move around and organize as desired by the owner. However, from the point of view of human health, the use of pots in the tropics may help attract dengue mosquitoes (*Aedes aegypti*), either inside homes or gardens (Pozo et al. 2007), becoming an even more alarming concern with new diseases transmitted by mosquitoes such as chikungunya or zika.

The significant results found in this research regarding garden area and absolute richness are similar to the results found by other authors. Jaganmohan et al. (2012) and Smith et al. (2005) found that the bigger the area the higher the richness of species in gardens, since there is a larger surface area to be planted. They also mention that this situation may be related to the level of interest of the owners (the most important factor in determining individual richness). They conclude that owners have control over flora richness in these private green spaces. This situation was also observed in the gardens analyzed in the city of Heredia.

Smith et al. (2005) justify a similar behavior in the richness of pioneer species with this predictor indicating that the bigger the garden, the less attentive the owner will be to eliminate the weeds.

With regards to the location of the garden in the property, the significant difference in richness found in category 3 (surrounding the entire dwelling) in relation to category 1 (in front of the dwelling–*antejardín* in Spanish) is that the former has a larger area dedicated to the garden, which offers owners a greater possibility to increase their collection, as stated by Smith et al. (2005). Category 1 (*antejardín*) fulfills other functions that involve planting, such as promoting adequate ventilation of the front rooms of the house as well as contributing to the safety of the people and the social relations between neighbors (Ordoñez 2008).

In addition, category 1 (*antejardín*) is not present in all houses. The absence of this category is more evident in some gardens in BB and HU. According to the urban planning regulations established in the Building Bylaws of the Costa Rican Institute of Housing and Urban Planning (*Instituto Nacional de Vivienda y Urbanismo-INVU*), this area should be present in developed areas such as BB, but due to the smaller size of the properties on this site and to the socioeconomic aspects discussed above, these green areas may end up being used to increase the habitable parts of the house. The HU is exempt from this standard because it is located in the urban quadrant (Metropolitan area) (Marco Ruiz, Municipality of Heredia (personal communication 2012).

Another interesting variable is the increased vegetation richness that accompanies older owners of gardens in Heredia. As indicated by Loram et al. (2011), those owners probably have more time to devote to these spaces, as well as higher income, less economic responsibilities, or are retired and use gardening as entertainment. Although there is very little data on this relationship, they believe that older and/or retired people play an important role in maintaining urban biodiversity.

Although age is a predictor of richness in this research, it also tends to decrease with the advanced age of the owner. Similar to this research, Madanes and Faggi (2008) found that interviewees older than 60 years of age had very little or no plants at all.

Some of the most important conclusions include the following: private domestic gardens in the city of Heredia contribute greatly to the plant diversity of this urban area and, as far as ecosystemic services, they may be providing habitat for wildlife and contributing to the quality of life of its inhabitants. However, the biggest challenge is to increase the number of native species in these urban green areas. In addition, we indirectly observed a relationship between the size of the garden, the vegetation richness and the socioeconomic level, which, related to public policies and urban planning, alerts us of the need to increase public green areas for communities with smaller garden areas to enjoy. Finally, municipal incentives must be created to preserve these urban green areas. Since they are private they are at great risk of extinction, especially in the Metropolitan area, where there is more real estate pressure on the ground due to the city's service and commercial functions at the expense of the horizontal family home, as it is predominantly the case in HU.

Acknowledgments We wish to thank Universidad Nacional de Costa Rica and those involved in the Pirro River Project researching an urban watershed in Costa Rica. We would also like to extend our appreciation to all the property owners of the gardens analyzed; without their permission we would not have been able to work in such private areas. Our gratitude also goes to José Pablo Castro-Chacón for preparing the map for this article and Randall Jiménez for the statistical analysis of the data.

Appendix 1. List of species of plants reported in more than 20 private domestic gardens.

Acanthaceae

* *Blechum pyramidatum* (Lam.) Urb.

Amaryllidaceae

"Zephyrantes sp.

Apiaceae

"*Centella asiatica* (L.) Urb.

* *Cyclospermum leptophyllum* (Pers.) Sprague

Apocynaceae

"*Catharanthus roseus* (L.) G. Don

Araceae

**Aglaonema commutatum* Schott

* *Anthurium andraeanum* Linden

* *Spathiphyllum wallisii* Regel

* *Syngonium podophyllum* Schott

Arecaceae

* *Chrysalidocarpus lutescens* H. Wendl.

Asparagaceae

* *Aloe sapo*naria Haw.

* *Chlorophytum comosum* (Thunb.) Jacques

* *Dracaena deremensis* Engl.

Asteraceae

"*Cosmos sulphureus* Cav.

* *Youngia japonica* (L.) DC

Balsaminaceae

"*Impatiens balsamina* L.

"*Impatiens repens* Moon

Caryophyllaceae

* *Drymaria cordata* (L.) Willd. ex Roem. & Schult.

Costaceae

"*Costus speciosus* (J. König) Sm.

^ *Costus stenophyllus* Standl. & L.O. Williams

Cucurbitaceae

^ *Sechium tacaco* (Pittier) C. Jeffrey

Euphorbiaceae

* *Codiaeum variegatum (*L.) Rumph. ex A. Juss

^ *Euphorbia prostrata* Aiton

Geraniaceae

* *Pelargonium hortorum* L.H. Bailey

Hydrangeaceae

* *Hydrangea macrophylla* (Thunb.) Ser.

Liliaceae

"*Lilium longiflorum* Thunb.

Nyctaginaceae

"*Mirabilis jalapa* L.

Orchidaceae

**Guarianthe skinneri* (Bateman) Dressler & W.E. Higgins

Oxalidaceae

* *Oxalis corniculata L.*

Piperaceae

* *Peperomia obtusifolia* (L.) A. Dietr.

Poaceae

* *Paspalum notatum* A. H. Liogier ex Flüggé

Polygonaceae

"* *Rumex crispus* L.

Rosaceae

* *Rosa chinensis* Jacq.

Rubiaceae

"*Coffea arabica* L.

Solanaceae

* *Capsicum annuum* L.

Thelypteridaceae

* *Thelypteris dentata* (Forssk.) E.P. St. John

Urticaceae

* *Pilea microphylla* (L.) Liebm.

Abbreviation: *present in more than 20 gardens, ^endemics," naturalised, underlined pioneers

Appendix 2 List of plant species under any special protection in private domestic gardens, Heredia, Costa Rica

Conservation Status Costa Rican Wildlife Conservation Law [LCVS (a) & (b)] and CITES (appendix II)*	Plant Family Genera & Species
(a) Reduced populations	**Orchidaceae Family**: *Barkeria lindleyana*, Brassavola nodosa*,Brassavola aff. Venosa, Brassia verrucosa*,Catasetum integerrium*, Catasetum maculatum*, Cattleya mosiae, Cochleanthes discolor , Elleantthus longibractetatus*, Encyclia chacoensis, Encyclia cordigera*, Encyclia fragans*, Epidendrum ciliare*, Epidendrum radicans*, Epidendrum stamfordianum*, Gongora claviodora*, Gongora quinquinervis,Guarianthe skinneri*, Isochilus major*, Laelia rubescens*, Lockhartia oerstedii*, Lophiaris carthagenensis,Lycaste bradeorum*, Lycaste brevispatha*, Maxillaria sp., Oncidium sp., Oncidium stenotis*, Scaphyglottis bífida*, Schomburgkia tibicinis, Schomburgkia undulata, Sobralia macrantha*,Sobralia sp. 1, Stanhopea ecornuta*, Stanhopea wardii*, Stanhopea saccata, Trichopilia marginata*, Trichopilia suavis*, Trigonidium egertonianum*, Vainilla sp.*
	Cactaceae Family: *Epiphyllum phyllanthus, Epiphyllum oxypetalum*, Epiphyllum thomasianum*, Hylocereus costaricensis*, Nopalea cochinellifera*, Rhipsalis baccifera*, Selenicereus wercklei**
	Zamiaceae Family: *Zamia sp.*
(b) Threatened with extinction population	**Orchidaceae Family**: *Arpophyllum giganteum*, Cattleya dowiana**

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