Socio-Economic Differences Control Species Composition of Urban Gardens in a Metropolitan Area of Argentina

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Abstract

Human population is becoming increasingly more urbanized, and in that context private gardens contribute to biodiversity and to access to ecosystem services in cities. The urbanized landscape reflects social, economic and cultural differences of the population, which affect the patterns of urban biodiversity. Socioeconomic level is one of the main factors that spatially structure cities, for which it likely influences several attributes of gardens. In this study we characterized urban vegetation diversity in 50 private gardens of an urban agglomerate of Argentina, Gran San Miguel de Tucumán. We aimed to determine which variables control ecological attributes of gardens. We used socioeconomic indicators obtained from the 2010 Nacional Population and Households Census, and data obtained through a survey to garden owners. Our study suggests that species composition of gardens responds to socioeconomic conditions, which might be linked to the exchange of species as the main method to obtain plants and to strengthen social bonds by belonging to a similar socioeconomic level rather than neighborhood or geographic distance. Based on our analyses, gardens in areas with higher socioeconomic level were larger. Species richness and socioeconomic level of gardens were not significantly associated, and species diversity was related to garden age, with older gardens being more diverse.

1. Introduction

Spatial structure of private gardens, which plays an important role in urban ecosystem biodiversity and life quality of people, might be associated with socioeconomic conditions. Private gardens are a key component of urban green areas, with an important role in the connection between urban green areas and the life quality of people (Rudd et al. 2002). Gardens can represent the majority of urban green areas, and their management is challenging due to the diversity of actors involved (Gaston et al. 2013). Gardens comprise one of the main scenarios for interactions with wildlife in cities, offering opportunities for the enjoyment of the natural environment (Power, 2005; Freeman et al., 2012) in a context in which human population is undergoing rapid changes towards a dominantly urban way of life (Grimm et al. 2008). Further, projections estimate that by 2050 75% of the world population will live in urban areas (Mills 2007). Most of this increase will occur in intermediate-sized urban areas (i.e., between one and three million inhabitants) of developing countries (Crossette, 2011). Private gardens are an important component of cities, and their governance and management have a substantial impact on ecosystem services provision and urban biodiversity maintenance (Loram et al., 2008; González-García & Sal, 2008; Peroni et al., 2016).

The role of private gardens on urban biodiversity is complementary to that of public green areas (e.g., parks, street woodlands). Private gardens are generally small but numerous, and thus they are an important component of urban nature conservation strategies (Loram et al., 2007; Goddard et.al., 2010). Most research focuses on public spaces and the benefits they provide both to the health of people and to biodiversity in cities (Chiesura, 2004; Boone et al., 2009; Dobbs et al., 2017). Studies addressing private gardens (Loram et al., 2008; González-García & Gómez Sal, 2008; Peroni et al., 2016) are underrepresented in the research of urban green areas, although in many growing cities the area they occupy and their biodiversity are larger than those of other urban areas (Thompson et al. 2003). Additionally, the social implications of each may be different: green public areas are special due to being surrounded by households, as providers of experiences with nature, and for their positive contribution to the environment, while domestic private gardens also provide privacy, freedom, and opportunities for gardening (Coolen & Meesters, 2011). Regarding species composition, humans import a wide variety of non-native plants to cities, for landscaping and other horticultural objectives (Reichard & White, 2001); thus, import of non-native plants is also an important cause of increasing plant species richness in urban habitats. The proportion of exotic species in urban environments is generally much larger among plants compared to other taxonomic groups, such as birds, mammals, reptiles or amphibians (McKinney, 2006).

In Argentina, it has been observed that when green spaces are a scarce commodity, their distribution is mainly related to socioeconomic variables; in which sectors with higher socio-economic level have higher access to urban vegetation (Spescha et al 2020). Since most urban green spaces are private (Gaston et al 2013), it is likely that much of this pattern is explained by the contribution of domestic gardens. It is important to highlight the importance of each type of green urban space to biodiversity: public spaces are managed by only one administrative unit, while private gardens have a more diverse management (Gaston et al. 2013) for which the contribution of private green spaces to biodiversity might be more relevant than that of public spaces.

Cities have socio-economic segregation related to the urban form, the provision of infrastructure, and the value based on location (Lima, 2001). Several studies have shown that a higher financial income in households is related to higher vegetation cover, and to higher access to the benefits provided by ecosystem services (Flocks et al., 2011); and that education level is also positively correlated with vegetation cover (Heynen & Lindsey, 2003). The social, economic and cultural differences of the population are reflected in the urbanized landscape, and explain the access to social and infrastructure services, affecting the spatial pattern of vegetation in urban ecosystems (Pedlowski et al., 2002; Hope et al., 2003; Pickett et al., 2008; Luck et al., 2009; Clarke et al., 2013, Spescha et al., 2020). Thus, since socioeconomic factors affect vegetation complexity, social and cultural factors could be expected to affect species richness and abundance (Kinzig et al. 2005).

Socio-economic level is one of the main factors which spatially structure cities, and it is expected to influence on many attributes of gardens. Several studies have found correlations between socioeconomic status and diversity of urban birds (Melles, 2005; Bradley & Altizer, 2007), and some ecologists have tried to quantify the scope of wildlife-friendly gardening (e.g., Gaston et al. 2007). The analysis of these patterns can be difficult due to the effect of “mimicry” or contagious processes in the structure of gardens, which increase spatial autocorrelation of the considered attributes. For example, in Vancouver, Canadá, vegetation and landscaping of neighboring gardens were observed to be more similar compared to those of different streets or neighborhoods (Zmyslony & Gagnon, 1998). It is important to identify whether the contagion process is due to the spatial distance or the socioeconomic distance, since it modifies the spatial structure of urban biodiversity, and the spatial replacement of species.

In our study, we analyze private gardens as socio-ecological components, and we seek to understand the interactions between socio-economic structure and urban vegetation diversity in private gardens of one of the main urban agglomerates of Argentina: Gran San Miguel de Tucumán. We seek to determine which variables control ecological attributes of gardens, considering that socio-economic characteristics can directly influence garden management, which is reflected in the heterogeneity of urban landscapes (Martin et al., 2004: Grove et al., 2006; Mennis 2006; Troy et al., 2007).

Our hypothesis is that people with higher income might dedicate more time and economic resources, and might have more access to information and resources for gardening, for which we expect a positive association between socio-economic level and species richness. However, it is likely that other attributes of the garden, such as age and area also have an influence on richness. Another hypothesis is that due to a “mimicry” process and to the exchange of genetic material, socioeconomic level also determines the identity of the species present in gardens, for which we expect to find an association between socio-economic level and garden species composition.

We analyzed the spatial and non-spatial relation of species composition and socio-economic level in a subtropical agglomerate of Argentina: Gran San Miguel de Tucumán. We characterized plant species diversity through sampling in 50 private gardens and a short survey to owners. We evaluated the relation between plant diversity with a socioeconomic index and the different variables obtained in the surveys to explain the pattern of species distribution. We used multivariate analyses to visualize the similarity patterns of species composition among gardens, and we evaluated whether the emerging pattern of these analyses responds to geographic distance or socioeconomic aspects.

2. Materials And Methods

2.1 Study area

The study area corresponds to the urban agglomerate Gran San Miguel de Tucumán (GSMT) (Fig. 1). GSMT is the main urban center of northwest Argentina, and it is the sixth largest city of Argentina and the fifth more populated (INDEC 2010). GSMT is located at the foothills of Sierras de San Javier, in a transition area between moist montane forests (Yungas) and dry lowland forests (Chaco), largely modified for agro-industrial activities. Climate is subtropical with a seasonal precipitation regime, leading to warm, rainy summers and cold, dry winters. Mean annual temperature is 19° C and mean rainfall reaches 1000 annual mm (Servicio Meteorológico Nacional, 2011).

The city was founded more than four centuries ago, and it was a pioneer in the sugarcane industry in and in the development of railways in Argentina, which led to its constitution as a socioeconomic and urbanization hub. This large urban center concentrates a population of 800,000 inhabitants (INDEC 2010) and it encompasses five departments: Capital, Cruz Alta, Tafí Viejo, Lules and Yerba Buena. These departments correspond to administrative units of third order according to the argentine system.

Tucumán has high social inequality compared to other provinces of Argentina (Spescha et al. 2020), which makes it a particularly useful system to evaluate the effects of socio-economic inequities.

2.2 Socioeconomic and population data

To spatially characterize the socio-economic level of the GSMT population we used data from the national population census, Instituto Nacional de Estadísticas y Censos de la República Argentina (INDEC). We analyzed the data of the urban agglomerate at the censal radii (CR) level, which is the minimal spatial unit of data aggregation (INDEC, 2010). The size of the CR is defined by the number of households; and each CR has an average of 300 households (INDEC, 2010),

The social characterization of the population is based on education levels and household infrastructure from the 2010 national census (Censo Nacional de Población, Hogares y Viviendas 2010, CNPHyV-2010). Each CR is georeferenced through a polygon which allows working in a Geographic Information System (GIS). To extract information of the censal variables we used the software REDATAM + SP (REcuperación de DATos para Áreas pequeñas por Microcomputador) (INDEC, 2010).

We used the Socioeconomic Status Index (SSI) to characterize the socioeconomic level of each CR. This index constitutes a conceptual and quantitative model that summarizes many social and economic aspects to characterize local population through material, infrastructure, and household context attributes (Spescha et al., 2020). The SSI has a continuous score between 0 and 100 and allows establishing groups (g) which encompass units with similar scores (1, 2, 3 ... .7), with 1 taking lower scores and 7 taking higher scores.

2.3 Vegetation Data

We sampled the vegetation of 50 private gardens of GSMT. To select the households, we carried out a stratified sampling as a function of estimated socio-economic level through the SSI. We took into consideration that samples corresponded to gardens of different CR, to encompass all the heterogeneity within the study area. One limitation to perform a strictly stratified sampling was accessibility to households, since we considered gardens whose owners had been previously contacted. Thus, although the spatial distribution of gardens encompassed the whole study area, representativeness by socioeconomic group was lower (Fig. 1). After selecting the gardens, we developed a protocol to visit the respective households, including records of the general characteristics of each garden and a short survey to characterize the owners. We filled a spreadsheet with data of the different gardens, with previous agreement of the owners.

We obtained data of the area of each garden, and we sampled all the plant species to describe species composition of each garden. To ensure that most of the common species were represented we took pictures or parts of the plant in the cases where the species could not be identified *in situ*, which we later identified through different means (bibliography, flora catalogues, herbaria, etc.). Certain groups of plants were not considered (e.g., poaceae), while others were grouped in families (e.g., cactaceae, orchidaceae). Species composition allowed us to quantify species richness and diversity considering the diverse life forms: trees, shrubs, herbaceous plants and climbing plants. The identification of species gave us information about their respective origins, and we distinguished among native (from South America) and exotic species.

We collected data to characterize the owners of the houses through a short survey, which included questions about characteristics of the garden and of their owners. The variables we used to build the survey were 1) Age of the garden 2) Dedication (time and people) 3) Level of studies reached 4) genera and 5) Age.

As we progressed with sampling in the gardens, we observed that a common behavior among surveyed people was to share opinions about how they obtained certain plants from their gardens, for which we considered it important to include in the survey questions about the origin of the species in their gardens, and how they had acquired them (e.g., through exchange or purchase).

Also, we included questions to evaluate whether people could differentiate among native and non-native species. Both questions were included in the surveys after sampling the sixth garden, for which we obtained answers in 45 out of 50 sampled gardens. These new questions were: which is the origin of the plants of your garden? (exchange or purchase); do you identify which species are native and which are not?

2.4 Social variables in relation to species richness of gardens

To analyze the relation between social variables and attributes of private gardens, we carried out lineal regression analyses between species richness and the following variables: age, gender of the person in charge of the garden, maximum level of education reached, time and dedication (hours per week), size of the garden, age of the garden and socioeconomic level (SSI).

Additionally, we analyzed the relation between size of the garden and socioeconomic level (SSI) through a linear regression to observe whether gardens of larger dimensions corresponded to CR with higher levels of SSI.

2.5 Analysis of plant species composition of gardens

We performed a multivariate analysis to represent the dissimilarities of species composition among gardens. Multivariate analyses allow summarizing multiple sources of variation in simplified axes. We used the Non-Metric Multidimensional Scaling (NMDS) method, which allows using species presences and absences to calculate dissimilarity using the Bray-Curtis formula. Once the distance matrix among gardens is obtained, the NMDS uses stochastic simulations to find a defined spatial arrangement in the smaller number of axes, which minimizes the inconsistencies with the observed distances (stress indicator). For that reason, each NMDS run can provide slightly different results. One advantage of the method is that the axes summarize complexity, and their values can be used in subsequent analyses. For this analysis, we considered species that were present in at least five gardens, and we used 96 species.

To identify the variable that best explains the distances in garden species composition we compared the adjustment of the obtained distances through the NMDS with the geographic and socioeconomic distances. For this analysis we used the Mantel correlation (Guillot & Rousset, 2013). Mantel tests are adequate for evaluating correlation between matrices. Their use became popular to evaluate how geographic distances explained structures of other variables considering autocorrelation. In the statistical significance analysis, the Mantel test uses permutations that calculate the probability of obtaining the obtained pattern with a null model. We compared two Mantel tests to determine whether spatial or socio-economic distances among gardens were better predictors of the botanic distances observed in the NMDS. Once each Mantel test was carried out, we evaluated the level of correlation (since they have the same number of observations and parameters) to determine which matrix had higher prediction power. All the analyses of this study were performed using R software (R Core Team, 2017).

3. Results

3.1 Garden characteristics

The most variable characteristic of the sampled gardens was their area, with a mean of 407.2 m^2 and a range between 50 and 1400 m^2. Average age of people in charge of a garden was 53 years; the youngest person was 25 years while the oldest was 89 years. The time dedicated to gardening varied from one to 13 hours per week, with an average of 5.22 hours/week (Table 1). Regarding garden age, we characterized them in three categories: less than five years old, five to 15 years old or older than 15 years.

Table 1
Summary of the characteristics of the gardens according to the data obtained in the survey.

Areas /characteristics	Mean	Median	Range	Variation range
Person in charge of the garden (age)	53.02	53	25–89	3.56
Weekly dedication (hs)	5.22	5	1–13	13
Size of the garden (m^2)	407.2	260	50 -1400	28
Family members	3.92	4	1–7	7

3.2 Plant composition

We recorded 270 species belonging to 98 families (Table 2). To analyze vegetation structure, we used a simplified life form classification. The most frequent life form corresponded to herbaceous plants, represented by 118 species. Among woody species, composed by trees and shrubs, we registered 92 species. We found 33 climbing species, while other groups of interest such as succulent plants, cacti and palm trees were also present but less represented. Regarding species origin, exotic species were more frequent, with 165 species, while native species were 105.

Table 2
Summary of species according to life forms, origin and families.

		Total species
	Herbaceous	118
	Trees	47
Life form	Shrubs	52
	Climbing species	33
	Palm trees	8
	Cacti and succulent plants	12
	Native	105
Origin		
	Exotic	165
	Species	270
Total		
	Families	98

Based on our results we defined older gardens (> 15 years) as the most diverse regarding plant species. Age and genus (male or female) of the people in charge were not related to species number; and neither was weekly dedication (in hours) to garden maintenance and species richness (Table 3).

Table 3
Summary of Regression Analysis.

Response variables	Predictor variables	R^2
	Age and genera of people	0.03
	Age of the garden	**0.24***
	SSI	0.19
Total richness	Garden area	0.01
	Education level	0.06
	Dedication (time)	0.02
	Dedication (people)	0.10
Garden área	**SSI**	**0.71****
*note *p < 0.001 **p < 0.0001*		

Regarding the origin of the species present in gardens, only four of the surveyed people knew whether the species were native or not. Additionally, approximately nine out of ten garden species were obtained through vegetative propagation and seeds, in both cases from a relative or friend.

3.2.1 Representative plant families

Among the 98 identified families, the most representative were Asteraceae, conformed by 16 species; Asparagaceae and Lamiaceae, with 11 species, and Araceae with 10. Other families represented by more than seven species were Bignoniaceae, Oleaceae, Apocynaceae, Arecaceae, Cactaceae, Euphorbiaceae and Fabaceae. There were also other families represented by less than seven species (e.g., Rutaceae, Myrtaceae, Begoniaceae, Solanaceae entre otras), and many were represented by only one species (e.g., Amaranthaceae, Buxaceae, Portulacaceae, Violaceae among others).

3.3 Results of the regression analyses between species richness and socioeconomic variables

The simple regression analyses (Table 3) show that species richness was significantly related with garden age ($R2 = 0.24$, $p = 0.002$), with older gardens being more diverse. The SSI did not associate to the total number of species found by garden ($R2 = 0.19$, $p = 0.093$). A similar result was registered regarding the person in charge of the garden and the total number of species ($R2 = 0.10$, $p = 0.084$); and the time dedicated to the garden and species richness ($R2 = 0.02$, $p = 0.372$). However, there was a positive relation between garden area and SSI ($R2 = 0.71$, $p < 0.0001$), with larger gardens occurring in CR with higher SSI.

3.4 NMDS results

Two axes of the NMDS were enough to summarize the variation of the dissimilarity matrix based on shared species among gardens. When gardens were labeled in function of their socio-economic level, extreme groups showing a restricted distribution in the bidimensional space were observed (e.g., g2, g3 y g7). Other groups had a more uniform distribution in the bidimensional space and functioned as a link among groups (g5).

When comparing the two Mantel tests to determine whether spatial distance or socio-economic distance among variables had higher capacity to explain the distance among species observed in the NMDS (Fig. 2) based on the correlation level, the variable that best explained distances in garden species composition was socio-economic distance (r = 0.28) while spatial distance (r = 0.08) was weakly linked.

4. Discussion

Our study explores an aspect that has been scarcely considered in literature, and reports that private gardens can contribute to structure and consolidate human groups. It is important to highlight that humans have the unique ability of accumulating culture (Dean et al., 2013), and particularly the use of plants for a wide variety of benefits is passed between groups and from generation to generation (Salali et al., 2016). The patterns found in our study suggest that garden species composition responds to socio-economic conditions, which is probably linked to the exchange of genetic material as a mechanism to strengthen social bonds. Although this type of analysis is not frequent, a similar pattern was found in Burundi (Bigirimana et al. 2012). In that study, the authors found that garden orientation was structured mostly as a function of socioeconomic level, being utilitarian among lower socio-economic levels, and ornamental among higher socio-economic levels. In contrast, according to our results, in Argentina garden orientation is related to aesthetic appraisal, but the effect of plant species tenure on socio-economic structure is maintained.

The distribution of vegetation is generated by mechanisms embedded in the tradition of exchanging plants with close people, for which it is appropriate to point out the corresponding differentiation of mechanisms for knowledge sharing and underlying social structure (Díaz Riviriego et al., 2016). Our analyses show that exchange between people is the main method to obtain plants. Species composition of gardens arises from such exchange and is defined mainly by belonging to a similar socio-economic rather than to neighborhood or geographic distance. Thus, it is likely that interpersonal relationships in the different socioeconomic sectors significantly affect patterns that structure gardens, thus reinforcing internal sectorial segregation within cities. It is also likely that urban plant communities tend to polarize following the socioeconomic polarization process observed in GSMT between 1991 and 2010 (Zamora & Rivas, 2017). One alternative in cities with sharp polarity, such as GSMT, could be the reinforcement of existing patches, taking into account that patches with contrasting communities could increase habitat for a higher diversity of associated species, such as birds (Haedo et al., 2017).

According to our analysis, gardens located in sectors with higher socio-economic levels are larger, although this does not imply higher plant species richness. This result is consistent with results obtained in other studies showing that higher socio-economic levels have higher access to green spaces, and to the benefits derived from ecosystem services (Flocks et al., 2011; Schwarz et al., 2015; Escobedo et al., 2015; Fernández & Wu 2016). Particularly in Argentina, it has been suggested that when property costs increase in densely populated cities, groups with less resources reach higher environmental quality (Spescha et al. 2020). Regarding species richness and garden socioeconomic level, we did not find a significant relation, which implies that vegetation in CS with higher SSI was not more diverse. These results differ from those of a study in New Zealand (Heezik et al., 2013), in which they found different patterns using a similar sample size, such as a positive relation between socioeconomic level and plant diversity, and between garden size and plant and bird diversity. In our analyses, species diversity was instead related to garden age, which suggests that, although peer plant exchange is the most frequent method of obtaining plants, older gardens might have more species richness due to longer time for material exchange and plant acquisition according to market trends of different periods.

Regarding the diversity of life forms registered in our sampling, herbaceous plants were the most representative, possibly because cuttings of herbaceous plants (commonly named “gajos” in Spanish) are easily shared and successfully propagated. Additionally, herbaceous species occupy less space, while trees, on the other hand, require a larger area. Thus, lower socio-economic groups might own less number of trees, since based on our results garden area was positively related to socioeconomic level.

In relation to species origin, urban gardens face many positive and negative challenges for biodiversity conservation, since on the one hand they maintain strikingly high species diversity, but on the other hand, the act as immigration sources from which exotic species can disperse in the surrounding landscape (Dehnen-Schmutz & Touza, 2008; Marco et al., 2008). It should be considered that the observed species richness patterns in gardens could be reflecting historical rather than current anthropic activities (Essl et al. 2010). In our study, 62% of the identified species in gardens were nonnative species, and most of the surveyed people were not able to identify native or exotic species, which represents a risk for the environment. Thus, we consider it important to reinforce environmental education, and to explain the potential effects of exotic species on the surrounding environment. Further, it should be highlighted that certain exotic plants can become invasive, with drastic consequences for biodiversity and ecosystem functioning (Pimentel et al., 2005). Thus, environmental awareness is a key factor to strike a balance in urban environments.

Using a novel approach, we described the association between socio-economic level and plant species composition in an urban system. However, it is important to mention certain limitations of our study, such as sample size, which is limited due to the effort involved in sampling each garden. However, studies carried out in countries with more resources had a similar sample size (e.g., van Heezik et al 2013). On the other hand, most of these studies are carried out in one city, and the only study addressing similar questions reached similar results (Bigirimana et al 2012). However, protocols to study this process in other contexts and to replicate our study in other sites should be designed to understand how gardens are structured in different cities. Finally, certain plant groups were more difficult to identify, but in general they involved particular species that were not very relevant for their owners (e.g., grass/poaceae). Other groups were identified only to the general level, such as Rosaceae and Orchidaceae.

5. Conclusions

We can conclude that, regarding factors modeling and structuring plant species composition in gardens of GSMT, garden age conditioned species richness, which might reflect the tradition of exchanging and “accumulating” plant species by their owners. This seems to be associated with belonging to a certain socio-economic level rather than to spatial distance. We consider that this study is an archetype that could be applied and adapted to different spatial scales and sites. This type of project could contribute to ongoing strategies regarding management of public green spaces through the knowledge of plant patterns in private gardens of a given territory.

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Figures

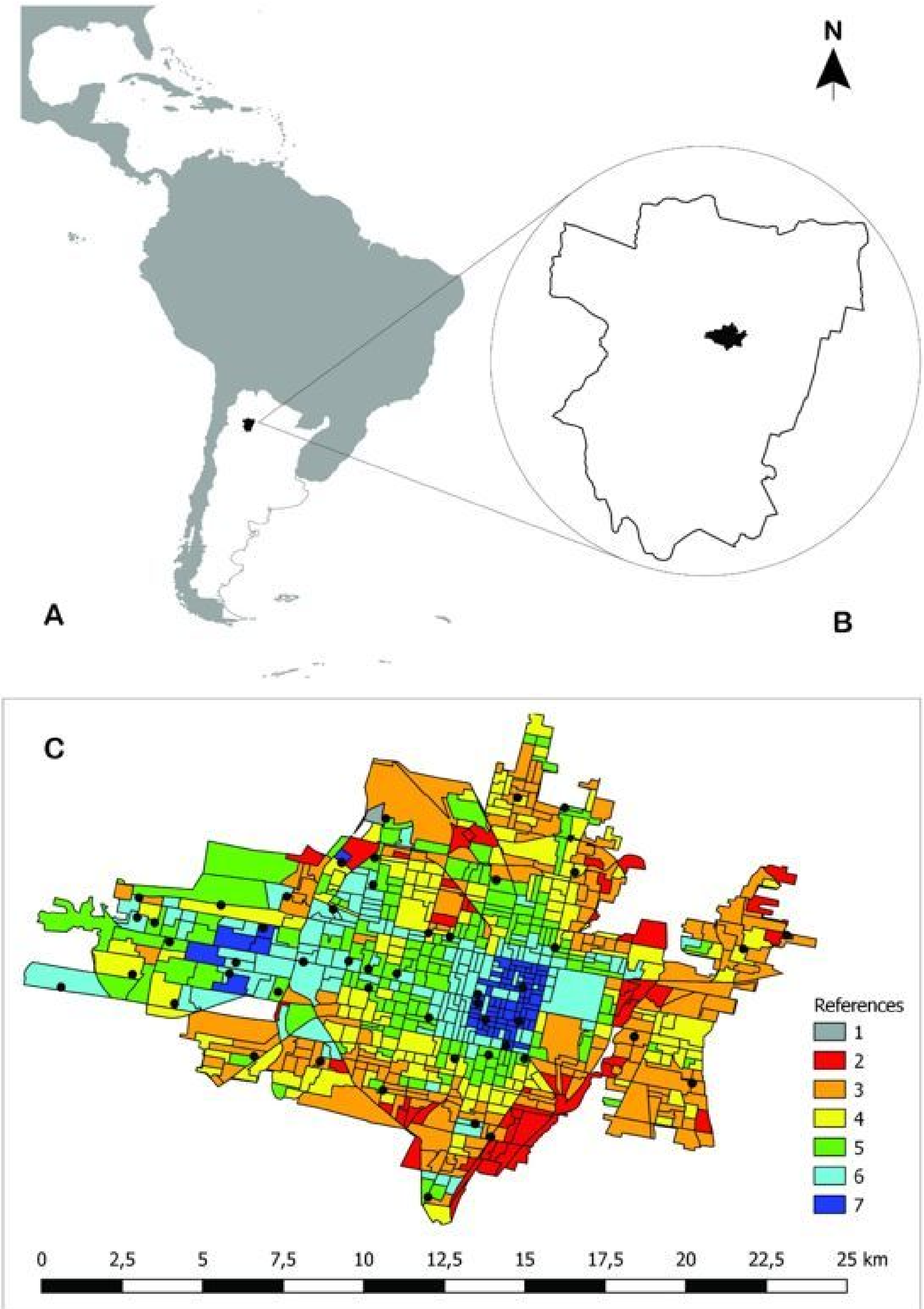

Figure 1

(A-B) Location of Tucumán province, Argentina in South America. (C) Places of San Miguel de Tucumán, and location of sampling sites in the study area. The colors show the different socioeconomic levels according to the SSI. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

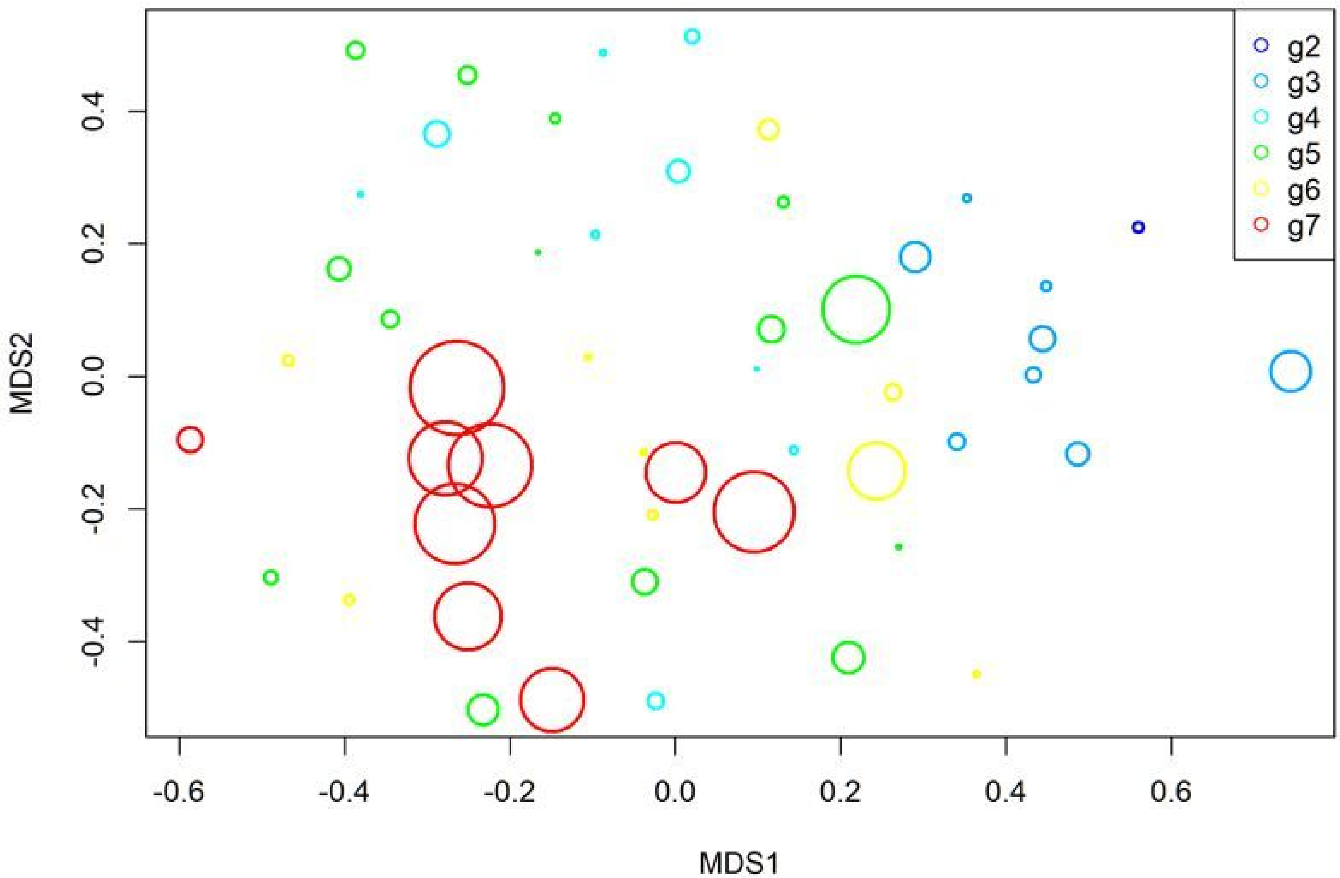

Figure 2

Multivariate analysis (NMDS) of the gardens according to the SSI and gardens size.

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