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The socioeconomics and management of Santiago de Chile's public urban forests

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Abstract

Santiago, Chile's semi-arid climate and urbanized environment poses a severe limitation for the establishment and maintenance of urban forests. Municipalities, or *comunas*, are the main stakeholders in the management of Santiago's public urban forests. A tenable hypothesis would be that as the socioeconomic level of a *comuna* increases, the better the condition of a *comuna's* urban forest. Unfortunately, there is little comprehensive information on management, public expenditure, and structure of Santiago's public and private urban forests. To examine this hypothesis, Santiago was divided into socioeconomic strata, then using air photo interpretation and stratified field sampling, urban forest structures were quantified by socioeconomic strata. In addition, interview surveys were used to determine municipal urban forest management and expenditures for different public urban forests based on socioeconomic strata. Urban forests in the high socioeconomic strata had fewer public trees, greater tree cover, tree and leaf area density, and leaf area index than lower socioeconomic strata. The percentage of total municipal budget allocated to public urban forest management was consistent among strata, but the total public urban forest budgets were greater in the high socioeconomic strata. Public urban forest structure is related to the socioeconomic strata of Santiago's different *comunas*.

Keywords: Municipal investment; Public expenditure; Urban forest management; Urban forest structure

Introduction

The Gran Santiago Area (GSA) is Chile's administrative, cultural, and industrial center. Despite having a fairly uniform climate, natural vegetation, and soil types (Donoso, 1993), Santiago's urban forest was already being modified by its native inhabitants, before its founding by the Spaniards in 1541. Today over 5 million inhabitants, 40% of the countries' population, occupy a semi-arid, urban–periurban area that includes: residential, industrial, and commercial districts, transportation networks, agricultural areas, and shrublands. Given the semi-arid and urban land use constraints, urban forest cover in the city is largely attributed to active management by its stakeholders. Thus it is likely that as stakeholders' socioeconomic level increases, urban forest cover and diversity increase and condition improves (CEC-PPR, 1995; Iverson and Cook, 2000; Pedlowski et al., 2002). However, there is little

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comprehensive information on management and expenditures in urban forests in the GSA and even less information on the differences in urban forest structure according to socioeconomic level for Latin America in general. This information can be important to city and urban forest managers, planners, and decision makers.

In the GSA, local governments, in the forms of municipalities or *comunas*, are in charge of providing the services and amenities for Santiago's urban inhabitants. The 36 *comunas* that constitute the GSA are autonomous with their own socioeconomic characteristics, mayor, council, and budgets. Laws and ordinances have given the responsibility of managing street trees and green areas in the GSA to the *comunas* (Ceballos Ibarra, 1997; Hernández et al., 2002). *Street trees* are trees within the right of way or easement of any major or minor thoroughfare. *Green areas* refer to parks, plazas, large medians, squares, shrublands, or any urban and periurban vegetated area. This distinction between street trees and green areas is consistent across most *comunas* in Chile (Ceballos Ibarra, 1997). For convenience, *public urban forests* in this study will be defined as street trees and green areas whose tenure and management responsibilities are within the department of *Aseo y Ornato* or the waste management and landscaping department of a *comuna* or other regional or national government entity. *Private urban forests* are other trees and green areas located on private property and maintained exclusively by private citizens. Finally, *urban forests* are the sum of all public and private urban forests within the GSA.

Chacalo et al. (1994), Conceisão Sanchotene (1994), Franceschi (1996), and Murray (1996) have studied urban forests in Mexico, Brazil, Argentina, and Ecuador, respectively. The focus of these and most Latin American urban forest studies though is mainly on *street tree* management, the overall state of urban forests, and specific urban vegetation components (Escobedo, 2004). Studies such as CEC-PPR (1995) and Iverson and Cook (2000) have used remote sensing to relate urban tree and vegetation cover to land-cover classes within an urban area and found that tree cover is related to higher income areas. De la Maza et al. (2002) in Chile and Pedlowski et al. (2002) in Brazil have found that urban forest tree diversity is related to socioeconomic wealth as well. In Europe, Pauleit and Duhme (2000) and Dana et al. (2002) studied urban forest and vegetation in the context of urban ecology and planning in Germany and Spain, respectively. However, the few studies that have analyzed urban forest structure (as defined in this study) and functions are in Beijing (Yang et al., 2005) and several North American cities (McPherson, 1998; Nowak and Crane, 2000).

Unfortunately, there is little information on urban forest management and structure in Chile. In 1995, the Catholic University of Chile undertook an assessment of the GSA's green areas (CEC-PPR, 1995). According to CEC-PPR (1995) in 1990, the municipal budgets destined for green area management varied from USD $16,000 in the *comuna* of Quilicura to USD $952,000 in the *comuna* of Santiago (1991 reference exchange rate of 313 pesos per USD). Santiago's *Intendencia*, i.e., regional government, carried out an assessment of street trees along eight major inter-comunal thoroughfares and found that in 1986 annual total maintenance costs varied from USD $115,000 in La Reina to USD$3,000 in San Ramon; an expenditure per tree of USD $4.00 and USD $0.10, respectively (1986 reference exchange rate of 191 pesos per USD) (Intendencia, 1987). Similar urban forest management, budget, and cost information from the United States is reported in Kielbaso et al. (1988).

A 1999–2000 diagnostic survey by the University of Chile describes the results of phone interviews with 34 municipal urban forest managers in Santiago (Rodríguez and Gonzales, 2000). The authors reported that 47% of the municipalities do not have any information on, or an inventory of, their street trees. Among these municipalities, 53% do not coordinate with any institutions and nearly 60% do not apply any fertilization or pest-control treatments to their street trees. Of all of the damages caused by trees, 37% are to infrastructure such as sidewalks and roads and 30% are to electrical lines (Rodríguez and Gonzales, 2000). The University of Chile also inventoried public urban forests in the *comuna* of La Reina (Hernández et al., 2002) and estimated that of the 50,577 trees and 203 species inventoried, 37,296 were street trees. No information was obtained in these studies on specific management activities or expenditures related to public urban forest management. Finally, as part of this same project, Escobedo (2004) analyzed the GSA's urban forest structure, function, management, and effectiveness as an air quality improvement policy.

Given the lack of information on specific management activities or expenditures related to public urban forest management in Chile and Latin America, this study will characterize urban forests in the GSA, particularly the amount of urban forests, the resources and expenditures associated with public urban forest management by the *comunas*, and determine if statistically significant relations exist between urban forest structure parameters and investment levels among the three socioeconomic strata. The results will provide one of the first comprehensive overviews of public urban forests and management in Chile. This paper investigates if Santiago's urban forest structure is shaped by the socioeconomic characteristics of its *comunas* and specifically, if the amounts of urban forest cover, proportion of public urban forest, tree numbers, leaf area, and tree density are related to management intensity and investment by Santiago's municipal governments.

Methods

Study area and socioeconomic stratification

The GSA's 36 *comunas* were assigned to one of three strata based on the percentage of households within the *comuna* in each of ICCOM Novaction's socioeconomic classes (ICCOM-Novaction, 2000). *Comunas* were systematically categorized into the high socioeconomic stratum if 20% or more of their households were in class *ABC1* (e.g., high average annual incomes, university-educated head of household, multiple car ownership). Medium socioeconomic stratum consisted of *comunas* with greater than 50% or more of the households in classes *C2–C3* (e.g., medium average annual income, working class, head of household with post-secondary education, single vehicle ownership) and *ABC1* and no more than 50% in classes *D* and *E* (e.g., low income housing, little post-secondary education, general lack of car ownership and fixed telephone service). The low socioeconomic stratum is comprised of *comunas* with 50% or more of the households in classes *D* and *E* (see ICCOM-Novaction (2000) for specific socioeconomic class grouping criteria) (Fig. 1).

Urban forest structure

The GSA lies at 450–900 m above sea level in the northernmost section of a basin referred to as the *Valle Central*, or central valley at 32°55′ and 34°19′ south latitude to 69°46′ and 71°39′ longitude west. Average annual precipitation is about 400 mm and the highly urbanized GSA (Table 1) is characterized by a temperate, semi-arid, Mediterranean climate with an average annual high temperature of 22 °C and average annual low temperature of 7 °C.

Urban forest and other surface covers were estimated for the 34 urban *comunas* using air photo interpretation of 1998 1:10,000 black and white and 2000 1:20,000 color, digital ortho-photos. Using a geographical information system (GIS: ARCVIEW 3.2 with a Spatial Analyst extension), the digital aerial orthographic photos were overlaid with 4355 random points, regardless of public–private tenure and land use, with each *comuna* having a minimum of 30 points. Individual photo points were classified as either: tree crown, building, pervious (e.g., bare soil, other vegetation), or impervious cover (e.g., asphalt, rock, or concrete) (Nowak et al., 1996). The relative frequency, in percent,

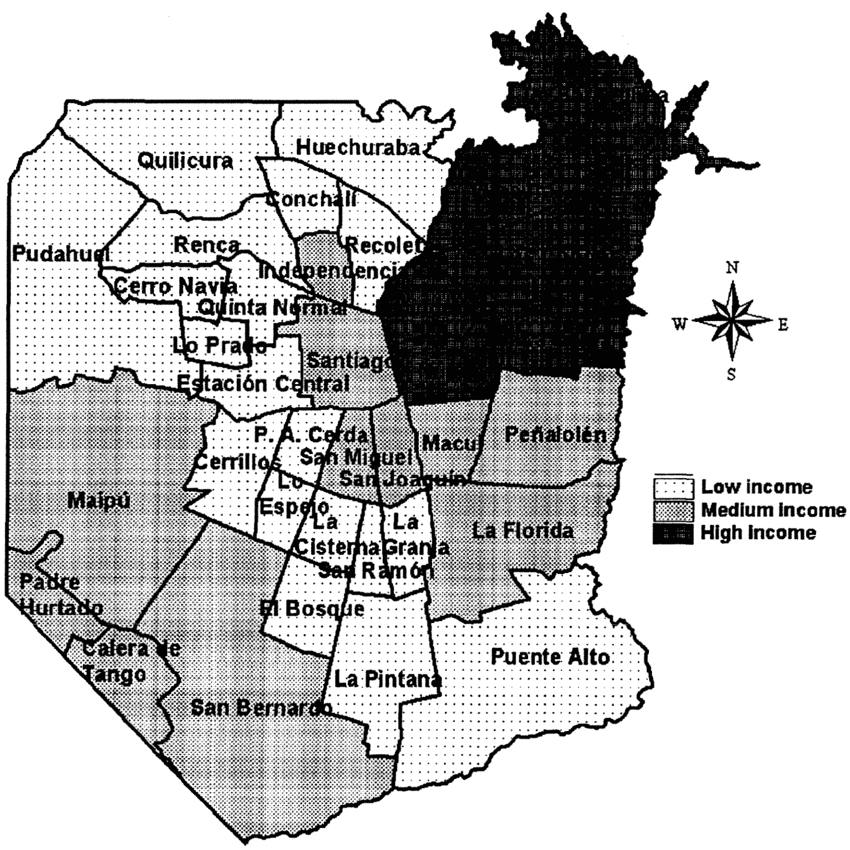

Fig. 1. Location, socioeconomic strata, and *comunas* within the Gran Santiago study area.

Table 1. Study area characteristics and demographics of the Gran Santiago Area

Strata	Area (km^2)	Percent of total population[a]	Number of *comunas*	Average annual per capita income (USD, 2004)	1995 Urban density (pop/km^2)[b]	2000 Population density (pop/km^2)[c]
High	164.9	14	6	10,000	4308	4691
Medium	370.3	35	11	4000	4328	5197
Low	431.9	51	19	1250	5694	6538

Source: ICCOM Novaction (2000) and Instituto Nacional de Estadistica-Chile statistics.
[a]Based on total population of 5.5 million in 2000.
[b]Does not include inhabitants living in rural portions of the *comunas*.
[c]Includes both rural and urban inhabitants within the *comunas*.

of points falling on the four separate surface covers was divided by the total number of points to yield percent: tree, building, pervious, and impervious ground cover over the entire study area. Standard errors for estimates of percent cover were calculated.

To obtain information on urban forest structure in the GSA, field plots were allocated using the GIS and the USDA Forest Service, Northeastern Research Station's Random Plot Selection Tool (www.fs.fed.us/ne/syracuse/Tools/tools.htm). Plots were assigned proportional to tree cover area for each of the three strata over the entire 967 km^2 study area, regardless of tenure or land use, and resulted in the high, medium, and low income strata having 74, 62, and 64 field plots, respectively. During January 2002, the two hundred 0.04 ha circular plots were located in the field and data collected for each tree on the plot with a minimum diameter at breast height (DBH) of 2.54 cm. Tree data measured included: direction and distance to tree from plot center, species, number of stems, DBH, total tree height, height to base of live crown, crown widths along a north–south and east–west axis, and indication if the tree bole was from a *street tree* or located on a *green area* and hence a public tree.

Plot data were input into the Urban Forest Effects (UFORE) Model to quantify *urban forest*: tree density, Leaf Area (LA) density, and Leaf Area Index (LAI) (Nowak et al., 2002). The UFORE computer model was developed by the USDA Forest Service Northeastern Research Station to quantify urban forest structure and function and aid in improving urban forest management and design (Nowak and Crane, 2000). LA in the UFORE model was estimated using regression models (Nowak, 1996), field canopy measurements, constant shading coefficients and adjusted for canopy overlap (Nowak et al., 2002). LAI was determined using regression equations relating canopy measurements and leaf area (Nowak and Crane, 2000). Standard errors given for leaf area estimates report the sampling error rather than estimation error. Estimation error is unknown and likely larger than the reported sampling error and includes the uncertainty of using equations and conversion factors, which may be large, as well as measurement error, which is typically very small. Detailed UFORE model urban forest structure parameter calculation methods are presented in Nowak et al. (2002) and Yang et al. (2005).

The null hypothesis that the GSA's urban forest structure is not shaped by the socioeconomic characteristics of its *comunas* was tested using nonparametric statistical tests. The Kruskal–Wallis rank-sum test analyzed tree density differences among the three strata (high, medium and low; d.f. = 2) and the Wilcoxon rank sum tested for pair-wise comparisons between strata (d.f. = 1, $\alpha = 0.05$) (Conover, 1999). Urban forest structure parameters estimated by regression equations were not analyzed statistically.

Urban forest management and cost survey

During January–April 2002, three *comunas* per socioeconomic strata were surveyed using a self-administered, semi-structured, open-ended questionnaire with in-person interviews (Poister, 1978). The nine *comunas* were selected based on representative socioeconomic characteristics of their particular stratum and existing working relationships and contacts with the urban forest managers. A larger sample size was limited by logistical and financial constraints. The person in charge of direct management of green areas and street trees was surveyed. Specific expenditure line items were determined from initial visits in November 2001 with personnel from (*Corporación Nacional Forestal* (CONAF); Chilean Forestry Corporation) and the *Comuna* of Vitacura. As part of the survey protocol, the manager filled out the questionnaire with the interviewer present (Poister, 1978). The questionnaire was left with the manager to permit the acquisition of additional accounting information and a final visit was scheduled to complete the questionnaire. The questionnaire consisted of three general areas: (1) amount of urban forest resources, including actual surface cover of green areas;

(2) budgets and expenditures for 2000 and 2002, and (3) management and maintenance activities.

Public urban forest budget amount is the total, fixed and variable, annual investment in the management of public urban forests and accounts for all expenditures including direct and indirect costs such as capital, labor, and operation (e.g., administration and overhead, maintenance activities, irrigation, fertilization, infrastructure improvement, and sidewalk construction and repair). Street tree expenditures were the costs of the direct management of trees within the right of way or easement of any major or minor thoroughfare. Green area expenditures were the costs associated with the direct management of parks, plazas, large medians, squares or any vegetated public, open-access areas in the *comunas*. Monetary amounts are normalized to USD for a specific year using the *Banco Central de Chile's* reported consumer price indices and the average monthly reference exchange rate (Ch$ per USD). Reported total annual municipal budgets for year 2000 were corroborated using documents from the Ministry of Comunal Planning (MPC, 2000). Although the sample size is small, the self-reported management budgets and expenditures should provide an order of magnitude estimate.

Results

Urban forest structure

Aerial photo interpretation resulted in a mean tree cover of 16.5% for the GSA (Table 2). Forty-three percent of urban forest trees sampled were publicly maintained and urban forest tree density across the GSA averaged 64.3 trees per hectare. The higher socioeconomic strata had a significantly greater density of trees than the medium and low socioeconomic strata (Table 3). There was no statistical difference in tree density between the medium and low socioeconomic strata. Santiago generally had open, widely spaced trees with little overlap in canopies. A relatively low mean LAI of 3.0 across areas with tree canopy is indicative of the GSA's semi-arid, Mediterranean shrubland environment (Scurlock et al., 2001). The high socioeconomic stratum's urban forests are characterized by greater tree cover, LAI, trees with a greater leaf area density, and greater densities of well-maintained trees. The low socioeconomic stratum had the highest percentage of public trees and building plus impervious surface cover (Tables 2 and 3).

Table 2. Estimated percent distribution of surface covers based on photo interpretation

Strata	Percentage estimated surface covers, SE (+/−)			
	Tree cover	Impervious	Pervious	Building
High	33.4 (4.4)	19.5 (3.7)	24.4 (4.5)	20.7 (4.4)
Medium	12.5 (3.2)	24.1 (4.3)	29.4 (4.5)	33.1 (5.0)
Low	11.8 (3.9)	28.6 (5.6)	29.7 (4.5)	29.5 (4.9)
GSA	16.5 (0.6)	19.1 (0.6)	42.6 (5.7)	19.5 (4.6)

SE, standard error; GSA, Gran Santiago Area; The *comunas* of Padre Hurtado and Calera de Tango were not included in this analysis due to lack of air photo coverage.

Table 3. Estimated urban forest structure characteristics

Strata	% Public trees	Leaf area index[a]	Total number of trees (1000s) SE (+/−)	Leaf area density (m^2/ha) SE (+/−)	Tree density (trees/ha) SE (+/−)
High	29	4.1	1663 (189)	10,602 (3005)	100.8 (11.5)**
Medium	38	2.6	2155 (363)	3200 (848)	58.2 (9.8)
Low	54	2.5	2401 (370)	3458 (828)	55.6 (8.6)
GSA	43	3.1	6219 (551)	4578 (710)	64.3 (5.7)

SE, standard error of the estimate.
The UFORE model does not currently provide a standard error of the estimate for leaf area index or % public trees.
**Significantly different at $\alpha = 0.05$, d.f. = 2.
[a]Leaf area index is for tree-covered area.

Municipal urban forest resources

Comunas in the high socioeconomic stratum had existing street tree inventories (Intendencia, 1987; Rodríguez and Gonzales, 2000; Hernández et al., 2002) and were able to quantify and report the actual number of street trees in the questionnaire (Table 4). Due to the lack of resources in the lower socioeconomic strata, *comunas* reporting existing tree numbers were estimates by urban forest managers and not based on actual data. According to survey results, the high socioeconomic *comunas* had a greater percentage of green surface area than *comunas* in the low socioeconomic stratum. Only the *comuna* of Santiago in the medium socioeconomic stratum had a percentage of green surface area comparable to *comunas* in the high socioeconomic stratum. Otherwise, the other two *comunas* in the medium socioeconomic stratum reported less percent of green surface area than the high socioeconomic stratum. Escobedo (2004) provides results of green area surface for the GSA based on photo and field sampling. Total municipal budgets were corroborated using MPC (2000) information.

Budgets and expenditures

The percentage of the total municipal budget allocated for public urban forest management appears to be consistent across all *comunas* and strata for 2002 (Table 5). The actual year-to-year total public urban forest budget (Table 4), however, varied due to government budget constraints, increased spending in infrastructure improvement projects, and other sociopolitical factors; although the relative amounts of the total municipal budget allocated to urban forest management remained consistent through time (Escobedo, 2004).

Per tree costs

Self-reported per street tree and maintenance expenditure costs were consistently greater in the high socioeconomic stratum. Total street tree expenditures per tree were greater in the medium socioeconomic stratum than in the low socioeconomic stratum. Average irrigation expenditures per strata in the semi-arid GSA were greatest in the high socioeconomic stratum and the

Table 4. Self-reported urban forest characteristics and total municipal budget

Strata	*Comuna*	Total surface area (ha)	Green area surface in hectares (% area of *comuna*)	Total number of trees		Total municipal budget (USD 1000)	
				2002[a]	1986[b]	2002	2000[c]
High	La Reina	2349	77 (3.3)	54,341	32,110	14,546	22,071
	Providencia	1424	76 (5.3)	42,000	44,440	67,149	86,064
	Vitacura	2542	63 (2.5)	44,000	—	37,909	56,216
Med	La Florida	4662	95 (2.0)	60,000	28,414	25,455	39,419
	Santiago	2280	74 (3.2)	75,000	33,983	109,091	146,766
	San Bernardo	10,471	44 (0.4)	80,000	—	24,545	28,160
Low	La Pintana	3102	48 (1.5)	60,000	16,472	13,636	31,116
	Pudahuel	7393	43 (0.6)	60,000	54,000	12,727	17,693
	Renca	2354	23 (1.0)	60,000	68,405	11,978	14,730

—, not reported; med, medium.
[a]Estimated number of public trees in green areas and streets.
[b]Total number of street trees according to Intendencia (1987) report.
[c]According to MPC (2000) documents.

Table 5. Mean proportion of the total municipal budget allocated to public urban forest management components as self-reported in the survey for 2002 and for 2000 based on corroborated MPC (2000) information

Strata	2002			2000
	% Green area expenditures	% Street tree expenditure	% Public urban forests	% Public urban forests
High	4.1	0.35	4.4	3.6
Medium	4.0	0.37	4.4	3.8
Low	4.7	0.29	5.0	3.0

Table 6. Self-reported per-street tree budget and maintenance expenditures for 2002 and total public urban forest irrigation expenditures for 2003

Comuna and socioeconomic strata	Total street tree expenditures (USD/tree)	Street tree maintenance expenditures in 2002 (USD/tree)	Street tree maintenance investment (percent of total 2002 street tree budget)	Irrigation (percent of total public urban forest management budget, 2003)
La Reina	1.79	0.51	28	15
Providencia	2.38	1.69	71	30
Vitacura	2.07	2.98	n	20[a]
High[b]	**2.08**	**1.73**	**n**	**22**
La Florida	1.73	—	—	—
Santiago	0.65	—	—	—
San Bernardo	0.75	0.20	27	11
Medium[b]	**1.04**	**0.20**	**n**	**11**
La Pintana	0.28	—	—	—
Pudahuel	0.53	0.20	38	19
Renca	1.00	1.59	n	3
Low[b]	**0.60**	**0.90**	**n**	**11**

Street tree maintenance specifically includes: pruning, planting, replacement, removal, emergencies, transplants, pest-disease treatments, fertilizer applications, and irrigation. —, not reported; n, not estimated.
[a]Estimate is for 2001.
[b]Mean for each stratum.

Table 7. Self-reported unit costs in USD/tree (cost/tree treated)

Comuna	Pruning	Planting	Pest-disease application	Fertilizer application	Removal	Emergency
La Reina	4.00	18.18	—	7.45	27.27	18.18
Providencia	13.64	—	10.05	0.43	15.45	20.00
Vitacura	18.55	30.91	0.93	—	61.82	27.27
San Bernardo	27.27	9.09	27.27	21.82	90.91	109.09
Pudahuel	18.18	—	—	—	27.27	41.82
Renca	15.00	6.73	—	—	59.64	44.91

—, not reported.
Note: the *comunas* of La Florida, Santiago, and La Pintana did not report unit costs in the survey.

same in the medium and low socioeconomic strata (Table 6).

Management efficiency

The operating, or management, efficiency is essentially the implementation of specified tree maintenance and tree care activities at a minimum cost and might indicate an optimum, cost-saving urban forest management system (Poister, 1978). An attempt was made to characterize the management efficiency of the different *comunas*. Differences in management efficiency among the strata might be due to the use of in-house municipal labor versus contracted labor and services or, the amount of available personnel, technical expertise, equipment performance, and available financial resources (Table 7). With the exception of planting costs, the *comuna* of San Bernardo in the medium socioeconomic stratum had the highest per tree costs. Planting costs were greater in the high socioeconomic stratum than the medium and low socioeconomic strata. Unfortunately, due to contract bidding clauses and stipulations, tree contractor unit costs could not be determined. However, street trees were generally maintained by municipal crews in the lower socioeconomic strata and green areas were maintained by contractors in all strata with the exception of a few *comunas* (Escobedo, 2004).

Discussion

As a result of the limited cost survey sample size, a direct correlation between urban forest expenditures and structure could not be determined. Other studies have noted the GSA's socioeconomic differences (Scarpaci et al., 1988; Bertrand and Romero, 1993). These differences in urban forest management were also expressed in the varying amounts of management activities, amount and types of available infrastructure, and in the investment in public urban forests according to socioeconomic strata. The total amount of monetary expenditure by *comunas* in their public urban forests did not seem to indicate differences in urban forest structure as opposed to the *comunas'* socioeconomic stratum and demographic characteristics. The high socioeconomic stratum was characterized by greater tree cover as well as LA and tree density.

Forty-three percent of all sampled trees in the GSA were public trees while CEC-PPR (1995) reported 51% of Santiago's green areas as public. Differences among strata echo findings for other studies relating increased tree diversity and condition to socioeconomic characteristics (De la Maza et al., 2002; Iverson and Cook, 2000; Pedlowski et al., 2002). The number of municipal trees reported for 2002 seems to be fairly consistent with the information provided by Intendencia (1987) (Table 4). National and regional government tree planting efforts in the lower socioeconomic *comunas* such as La Pintana and Pudahuel may account for increased tree numbers from 1986 to 2002 (Arenas Armijo, 1999). In 2002, 53,000 trees alone were planted in these two *comunas* (Illesca, personal communication).

The overall patterns per stratum of municipal budget allocation to urban forest management are fairly consistent among years and even strata. According to the managers, most of the green area expenditures were incurred in the form of maintenance and management contracts awarded to contractors. These expenditures might account for the difficulty in the determination of activity-specific costs related to tree management in green areas and the discrepancy between expenditures related to green areas and street trees. Also, the actual amount in hectares of green areas does not reflect the difference in structure since green areas in the high and medium socioeconomic strata were characterized by greater vegetated cover particularly in trees and grass and overall increased infrastructure (Escobedo, 2004).

The difference between overall tree management and maintenance expenditures per tree could possibly be used as an indicator of management efficiency and direct investment in actual tree maintenance as opposed to overhead-administrative expenditures. The greater per-tree maintenance expenditures in the *comuna* of Renca might be due to regional and national government programs that pay unemployed citizens via tree maintenance. The per tree expenditures in Vitacura are likely due to several expensive transplants of large mature trees carried out as part of an infrastructure improvement project (Reyes, personal communication). Maintenance expenditures per tree varied and might be a result of differences in definitions of urban forests and lack of information on *comuna* tree numbers. Irrigation costs might reflect more drought-resistant species compositions or conversely, higher water use species and, or different watering efficiencies in the *comunas* of the semi-arid GSA.

The differing management activities and expenditures in the GSA are likely related to the amount of financial and technical resources available for use by the *comunas* and the specific situations, or conditions, present in that *comuna* during the specific fiscal year. This was evidenced by this study's survey results and by Rodríguez and Gonzales (2000). In general, maintenance activities and management is reactive and deals with *comuna*-specific emergency situations rather than carrying out mid- or long-term plans and activities. As a result, total public urban forest budgets are greater in the higher socioeconomic strata, but the proportion of the total municipal budget that is allocated to public urban forest management by the different *comunas* in the three strata is consistent.

The socioeconomic characteristics, education levels, municipal and urban forest budgets, and land use zoning of the high socioeconomic stratum are similar to those of industrialized countries. Medium and low socioeconomic strata are more typical of Latin American municipalities, which are characterized by inconsistent fluctuating economic activities, spontaneous settlements, and lack of urban land use planning (Bertrand and Romero, 1993). For example, subsequent analysis of ICCOM Novaction (2000) survey during 2004 indicated shifts between the low and medium socioeconomic ranking of many *comunas* such as La Cisterna and Puente Alto.

Conclusion

An assessment of urban forest structure as expressed in the percentage of public urban forest, tree cover, tree density, LA density, LAI, and number of trees reveals differences in structure among socioeconomic strata in the GSA. Examination of the *comuna*'s urban forest management characteristics revealed that the high socioeconomic stratum had fewer public trees but greater tree cover, tree and LA density, LAI, and aerial surface of green areas than did the lower socioeconomic *comunas*. Relating management efficiency to specific socioeconomic strata was explored but could not be met in this study. Employment programs, contract clauses, and specific infrastructure improvement projects can be factors in the inability to relate these data with a specific stratum.

Although most *comunas* have variable, annual public urban forest management budget and vary in the numbers and types of maintenance activities, the proportion of the total municipal budget allocated for public urban forest management and the proportion of the total public urban forest budget allocated to the different management activities was relatively consistent through time according to socioeconomic strata. Since this study is based on three major socioeconomic strata in the GSA, the information provided by these results can be used to extrapolate the allocation of municipal budgets for public urban forest management to other *comunas* with similar socioeconomic characteristics. These results could also be used in future research to design urban forest management systems to maximize benefits to urban environmental quality and human well-being. Other studies might also address the role private landowners have on the GSA's urban forest structure and function.

Comunas in the low socioeconomic stratum relied on municipalities for their urban forests due to harsher growing conditions, lack of resources, limited incomes and fluctuating economic activity. *Comunas* in the high socioeconomic stratum have greater tree cover and tree and LA density due to the greater income and resources of their populace and municipalities. Population density does not seem to play a role in public expenditure in the urban forest resource whereas the socioeconomic characteristics of that *comuna* do appear to determine the amount of public urban trees, tree cover, tree and LA density and LAI. Given these results, urban forest structure, quantity, maintenance, and overall condition is associated with management intensity and investment by the GSA's municipal governments and the socioeconomic characteristics of each stratum.

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