Do water requirements of Mediterranean gardens relate to socio-economic and demographic factors?

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ABSTRACT

Gardeners can consume a large proportion of total domestic water, depending on their garden type and gardening style. We calculated water requirements of gardens based on species composition and land cover, and determined whether they can be predicted from the socio-economic, demographic and cultural characteristics of households. We recorded the plant species composition, garden cover types, and household characteristics of 258 households in suburbs of the Mediterranean coast of Catalonia. The distribution of the 635 species in these gardens were the input to a cluster analysis, in which semi-natural gardens, vegetable gardens, lawn gardens and ornamental gardens formed strong floristic groups, with ornamental gardens predicted to require the least water inputs and lawn gardens the most. We conclude that only income and a lack of work were related to our water requirement variable, reflecting the expense of water and the propensity of the retired to spend more time in the garden.

KEYWORDS

Private landscapes; landscape water needs; plant species composition

1. Introduction

Gardens provide physical and mental benefits while favoring private leisure and social interaction (Bhatti and Church 2000). Everyday human-plant relations lead to cultural landscapes that reflect shared customs, the original decisions of developers, and the ideals of residents (Gobster et al. 2007). Species composition strongly relates to the socio-economic attributes of homeowners (Hope et al. 2003, Kirkpatrick et al. 2007, Marco et al. 2010, Bigirimana et al. 2012). The influence of motivations and attitudes, including aesthetic preferences, on garden characteristics can also be strong (St. Hilaire et al. 2010, Kendal et al. 2012, Kirkpatrick et al. 2012, Van Heezik et al. 2013). In an example of the way in which these predictors work together, the presence of lawn in gardens relates to the price of water, level of education and the degree of awareness of the importance of water conservation (Domene and Saurí 2003, Hurd 2006).

The nature of particular gardens strongly affects water use (Askew and McGuirk 2004) in a context in which global climatic change has been predicted to further exacerbate water scarcity. About half of domestic water consumption in Australia (Syme et al. 2004), the United States (Mayer et al. 1999) and Spain (Domene and Saurí 2006, Salvador et al. 2011) occurs outdoors, making an understanding of the ways in which society, culture, demography and environment interact to create gardens with varying water requirements important in the planning of water conservation.

Records of domestic water use do not usually differentiate between house and garden (Salvador et al. 2011). However, estimates of water use in different types of gardens can be based on the known requirements of the components of the garden (Nouri et al. 2013). This process assumes an efficiency in use that might not exist (Fernández-Cañero et al. 2011, Salvador et al. 2011), perhaps explaining why calculated absolute landscape water needs do not necessarily predict water use (Domene and Saurí 2003, Salvador et al. 2011), but is robust for comparisons between garden types in particular areas.

The Catalan Spanish Mediterranean coast has experienced a recent marked expansion of low-density residential developments consisting of single-family houses with private gardens (Muñoz 2003, EEA 2006), a substantial proportion of which are owned by foreign nationals who are not permanent residents. These gardens constitute most of the vegetation within these coastal suburbs (Domene and Saurí 2003). The high socio-cultural diversity of these suburbs (Statistical Institute of Catalonia 2013) makes them an ideal study area for the investigation of causes of variation in garden water use. To date, influences of household socio-demographic characteristics on landscaping patterns have been shown (García et al. 2013a), but there has been no investigation of the relationships between socio-economic attributes of the residents and garden water needs.

We take the garden itself as the centrepiece of the water conservation problem, applying the Water Use Classification of Landscape Species (WUCOLS) method (Costello et al. 1994, 2000, 2014) to deduce landscape water requirements from species composition and the area of each type of ground cover. For our study...
area on the Catalan coast (Spain), we know that different elements of garden design are associated with different levels of water use (Padullés et al. 2014).

In the present paper we aim to: (1) obtain an empirical classification of garden types based on floristic distribution; and, (2) determine whether variation in garden plant composition and water requirements can be predicted from the socio-economic and demographic characteristics of the householders.

2. Method
2.1. Study area
The study was conducted in environmentally homogeneous low-density residential areas of five municipalities in the Alt Empordà region (42°14’53” N, 3°6’47” E) in Catalonia, Spain (Figure 1). We chose all residential suburbs located on the plain in the mouths of the Muga and Fluvià rivers where the average elevation is 9.2 m above sea level, the daily average temperature is 15 °C, varying from 30 °C in summer to 3 °C in winter (Meteorological Service of Catalonia 2013) and the average annual rainfall is 623 mm. The average reference evapotranspiration (ET₀) during the summer months (July, August and September) is 104 mm (RuralCat 2012).

Approximately 38% of residents are foreigners, mostly from France and Germany (Statistical Institute of Catalonia 2013). Currently 68% of houses are secondary residences only occupied for some portion of the year, particularly the summer months. The population density of the study area (including high-density urban areas) is high (351.90 people km⁻²).

2.2. Sample selection
Using ArcGis 10 (ESRI 2013) and the information contained in the Spanish official cadastre (Directorate General for Cadastre Electronic Site 2012), a layer with 6586 detached, semi-attached and attached single-family houses in the study area was obtained from which a representative sample of 258 households was randomly selected using the subset features tool in ArcGis 10 (ESRI 2013). A sample size calculation based on a Poisson distribution also confirmed that this sample includes a sufficiently large proportion of the population to be representative.

2.3. Data collection
Between May to late July 2013, all plants species were identified to specific or generic level in garden beds, pots and ponds by garden cover type (lawn, vegetable garden, uncultivated vegetation and ornamentals [trees, shrubs and flowers]) for each garden. A randomly selected plot of 0.5 m² was inventoried in lawn. Scientific nomenclature follows the International Plant Name Index. Each species was assigned to one life form according to the Raunkiær (1934) classification. Taxa were assigned to native or non-native categories using Sánchez et al. (2000) and Bolós et al. (2005).

To measure the area of outdoor land covers (hard surfaces, swimming pool, vegetable garden, uncultivated vegetation, synthetic lawn, lawn and ornamentals [trees, shrubs and flowers]) for each block in ArcGis 10 (ESRI 2013) we used the information gathered during the field survey and georeferenced orthoimages of 0.1 m × 0.1 m pixel size obtained from the Cartographic Institute of Catalonia.

A closed questionnaire was used to obtain information on socio-demographic and housing characteristics from the household who took primary responsibility for the garden (Table 1). We also obtained information on household water consumption during 2012, water sources used to irrigate the garden and the mode of garden watering from a subset of respondents. The water pricing structure in the study area consists of a two-part tariff in which a volumetric tariff (increasing-block tariff) is combined with a fixed charge.

2.4. Calculation of landscape water requirements
We used the WUCOLS method proposed by Costello et al. (1994, 2000, 2014) to estimate landscape water requirements (LWR). The WUCOLS method approximates the water needed to achieve an acceptable level of plant health and aesthetics in cultivated ornamental landscapes. A study recently conducted in South Australia concluded that this technique produces the best estimation of urban vegetation water requirements (Nouri et al. 2013), and it has been used widely in Spain (Domene and Saurí 2003, Salvador et al. 2011, Hof and Wolf 2014, Padullés et al. 2014). Specific procedures related in this section largely follow Padullés et al. (2014).

The technique is based on the application of a landscape coefficient, K_L, which is directly proportional to the species

Figure 1. Location of the surveyed low-density residential areas in Catalonia.
factor (k_s), the density factor (k_d) and the microclimate factor (k_mc) (Equation 1)).

\[ K_L = k_s k_d k_{mc} \]  

(1)

The k_s parameter depends on the type of plant and the related water requirements. Costello and Jones (2014) tabulated these values for more than 3000 ornamental species in six areas of California. Species were classified as presenting very low requirements (VL; k_s < 0.10), low requirements (L; 0.10 < k_s < 0.30), moderate requirements (M; 0.40 < k_s < 0.60), and high requirements (H; 0.70 < k_s < 0.90).

The k_s values for the first Californian areas were used. Species with VL water requirements were given a k_s of 0.1, while average values were used for L (0.2), M (0.5), and H (0.8) categories. Lawn species were classified as cool season grasses (k_s = 0.8) or warm season grasses (k_s = 0.6) following Costello et al. (2000). Plants grown for edible purposes were assigned to H water requirements as they were grown for food production. All cacti not included in Costello and Jones (2014) were assigned to L. To meet the standard conditions proposed by Costello et al. (2000), both weeds and species in containers or ponds were excluded from this part of the study. Only 50 species (7.9%) were discarded because they do not appear in the WUCOLS list.

The k_s factor for the three cultivated garden covers for each block was taken to be the maximum k_s for species listed under that cover. Plots containing only uncultivated vegetation were assigned a k_s of 0.4 as they were watered in almost all cases. Paved areas and synthetic lawns were assumed to have zero water needs.

The density of vegetation (k_d) and microclimate (k_mc) can modify K_L. The k_d factor has a range of 0.5–1.3 and reflects the collective leaf area of all planted species (Costello et al. 2000).

In the present study, a value of k_d = 0.8 was used for vegetable gardens and vegetation with one stratum. Lawns, or vegetation with two strata, were given a k_d of 1.0. Vegetation with three strata was assigned a k_d of 0.4 as they were watered in almost all cases. Paved areas and synthetic lawns were assumed to have zero water needs.

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2.5. Data analysis

A Bray-Curtis dissimilarity matrix was ordinated in one to four dimensions, using non-metric multidimensional scaling (NMDS) (Kruskal 1964) in the vegan package in R 3.0.3. Socio-economic, demographic and cultural linear vectors (Table 1) were fitted on the ordination. The type of residence (permanent vs. secondary) and the average age of family members were omitted due to collinearity with other variables. Transformations were applied to the variables in order to reduce skew and to improve the normality of residuals. The age of the building and the percentage of unemployed and retired people were squared while the number of residents was natural-log transformed. Categorical variables were coded as dummy variables.

A cluster analysis was conducted to obtain an empirical classification of the different landscapes. First, a hierarchical clustering using Ward’s method and Euclidian distance was performed on the ordination scores for four dimensions. Then, the centroids of the optimum solution were used as a seed for a k-means classification. SPSS (SPSS, Inc. 2010) software was used.

We identified indicator species of each assemblage using the IndVal method proposed by Dufrene and Legendre (1997). This asymmetric technique is based on an indicator value index that takes into account the presence or absence of species in a prior partitioning of sites (Legendre and Legendre 1998). We determined whether the average values for structural variables were significantly different between the clusters using non-parametric Kruskal-Wallis tests in R 3.03. When the result was significant, post hoc paired comparisons were performed following Dunn (1964). The Chi² statistic was used to determine the strength of relationships between categorical variables and garden types. In this case, post-hoc tests were based on adjusted standardized residuals following the methods proposed by Beasley and Schumacker (1995). Spearman’s rank correlation coefficient was used to analyze correlations between continuous numerical variables.

A stepwise linear regression to assess which variables were related to landscape water requirements was run with R 3.0.3. Thirteen out of the 258 cases were excluded from this part of the analysis due to missing data. The best model was considered to be that with the lowest Akaike Information Criterion (AIC) value. The variables selected in the vector fitting process were included in this model (Table 1). The same transformations were also applied to meet assumptions of normality and homoscedasticity. No dummy transformations were applied to ordinal categorical variables in this case. A significance level was established at $p < 0.05$.

There were 97 surveyed households for which water use data were available. We calculated the rank order correlation between LWR and domestic water consumption during the hottest season for the subset (97) of households for which water use data were available for the third trimester of 2012.

3. Results

3.1. Garden flora and plant assemblages

A total of 635 taxa were recorded from 258 gardens. The most abundant taxa were Rosa spp. (151 cases), Olea europaea (118), Euonymus japonicus (114), Citrus limon (112) and Phoenix canariensis (108). More than half of the species were trees or shrubs (phanerophytes 40.72%, chamaephytes 21.70%). Hemicyryptophytes constituted 14.31% of all species, therophytes 14.15%, geophytes 8.18% and epiphytes 0.94%. Eighty-two percent of the taxa were ornamental, 15% were weeds and 11% were edible.

The mean outdoor area of all plots was 296.5 m². The vegetated part of the outdoor area occupied, on average, 46.6% (138.3 m²) of this surface. Lawn covered an average of 5.9% of the outdoor area and ornamentals 37.2% (Table 1).

Four garden types were discriminated (Table 1, Appendix 1). The semi-natural gardens ($n = 57$) were large, mainly consisted of uncultivated vegetation and species (e.g. Conyza sp., Sonchus tomentosus or Dactylis glomerata). They were dominated by phanerophytes and hemicyryptophytes. Few of the indicator species required watering. Vegetable gardens ($n = 67$) were the smallest in area but the richest in species. The percentage of edible plants (e.g. Allium cepa, Mentha sp. or Solanum lycopersicum) was the highest of all groups. Ornamental plants and weeds were also species-rich. The vegetables and some ornamentals required supplementary water. Lawn gardens ($n = 59$) were characterized by lawn taxa (Festuca arundinacea, Lolium perenne and Poa pratensis) and ornamental species (e.g. Olea europaea, Citrus limon or Cupressocyparis leylandii) and the high proportion of the garden occupied by lawn and hard surfaces. Ornamental gardens ($n = 75$) were dominated by ornamentals trees and shrubs (e.g. Nerium oleander, Lantana camara or Callistemon citrinus) among a high level or hard surfaces. Both the percentages of garden area occupied by synthetic lawn and pool were the highest of all groups. A large proportion of indicator species had very low or low water requirements while almost one third had moderate water needs.
Variation in floristics (Figure 2) was most strongly related to high occupancy rates ($R^2 = 0.29$), foreign residents ($R^2 = 0.23$), Spanish non-Catalan residents ($R^2 = 0.18$), high income ($R^2 = 0.17$) and the percentage of non-working household members ($R^2 = 0.16$) (all $p < 0.001$). The age of buildings, low occupancy rates, the number of residents, primary education and low income were also related to floristics at $p < 0.05$, whereas there was no relationship with the duration of occupancy or higher education.

3.3. Predictors of landscape water requirements

The best socio-demographic model for landscape water requirements (AIC = 4378.45) included income ($p < 0.01$), the percentage of non-employed members of the household ($p < 0.01$), the occupancy rate of the house ($p < 0.1$) and the duration of occupancy ($p < 0.1$) (Table 2). A comparison of the standardized coefficients indicated that the value for income was greater than values for all other variables, followed by the percentage of unemployed members, the occupancy rate of the house and the duration of occupancy; all coefficients were positive.

3.4. Irrigation systems and water supply sources

A positive correlation was found between the LWR and summer water bills (Spearman’s $\rho = 0.435$, $p < 0.01$), indicating that garden water use contributed substantially to household water consumption. Eighty-four percent of surveyed residents

### Table 2. Stepwise linear regression effects of socio-economic and demographic variables on landscape irrigation requirements ($R^2 = 9.1\%$) in Catalonia ($^*p < 0.05$, $^{**}p < 0.01$).

| Variables                      | Unstandardized coefficients | Standardized coefficients |
|-------------------------------|-----------------------------|---------------------------|
|                              | B              | Std. error | β         | t-value | P      |
| Intercept                     | -1279.91       | 6213.03    | -0.154    | -2.059  | 0.018* |
| Percentage of non-working members | 0.51         | 0.19       | 0.184     | 2.622   | 0.009**|
| Income level                  | 3641.69        | 1190.05    | 0.149     | 3.060   | 0.003**|
| Occupancy rate of the house   | 2513.18        | 1303.09    | 0.149     | 1.929   | 0.056* |
| Years since living in the house | 2342.04      | 1243.11    | 0.132     | 1.884   | 0.061* |

Figure 2. Result of the non-metric multidimensional scaling (nMDS) for the flora of 258 inventoried gardens on the Mediterranean coast of Catalonia (stress = 0.18). Symbols represent each typology of garden according to the legend. Significant ($p < 0.05$) socio-economic, cultural and housing gradients are plotted on the ordination as vectors. Arrows have been added to categorical variables for a more understandable representation of the results. Length of the vector is positively related to the strength of the gradient: AB is age of the building, BS refers to Spanish non-Catalan owners, BW is for residents born in rest of the world, HI is high income, HO is high occupancy rates, LI is low incomes, LO is low occupancy rate, PE is primary education, NR is equivalent to the number of residents in the house and NW refers to the percentage of non-working household members.

Figure 3. Percentage of sampled gardens using distinct irrigation systems according to the four garden categories in Catalonia. Chi$^2$ tests were performed and different letters indicate significant differences ($p < 0.05$) among classes.
irrigated their gardens with water from the public network. Water from private wells was used in 7% of all cases, while only 5% used rainwater tanks alone or in combination with water from other sources.

Irrigation by hose was by far the most popular system, used by more than 50% of the householders in each group (Figure 3). Sprinkler irrigation was the second most used system, except in ornamental gardens, in which watering cans played a strong role. The proportion of houses using sprinkler irrigation was significantly higher in lawn gardens than in other garden types (Chi² = 12.156; p < 0.01). Drip irrigation was little used.

4. Discussion

4.1. Garden features and household attributes

The high gamma diversity of our gardens is not unusual (Smith et al. 2006, Marco et al. 2008, Bigirimana et al. 2012, Van Heezik et al. 2013). Neither is the strong influence of socio-economic and demographic attributes of garden owners on garden characteristics (Kirkpatrick et al. 2007, Marco et al. 2010, Bigirimana et al. 2012). The high proportion of holiday or permanent houses for foreign retirees makes our Catalonian suburbs very different from other similar communities in the U.S. (Osmond and Hardy 2004, Sovocool et al. 2006, Harlan et al. 2009, Polebitski and Palmer 2010). Nevertheless, there may be a maximum level of income at which water consumption is maintained despite an increase in wealth (Flörke and Alcamo 2009, Polebitski and Palmer 2010). Due to the particularities of each garden and a lack of standard methods for estimating parameters, such as irrigation efficiency, deviations of LWR from real garden water use must occur.

Our study focused on the relevance of socio-economic, demographic and cultural factors of homeowners on LWR. Local policies, the pricing of water, the presence of professional water managers, the legacy of urban developers, differences in attitudes within socio-economic and demographic classes, residents’ gardening motivations, their backgrounds and their socio-professional status, may also influence outdoor water use (Head et al. 2004, Larsen and Harlan 2006, St. Hilaire et al. 2010, Garcia et al. 2013b).

4.2. Factors related to garden water needs

Household income was the best predictor of the tendency to have a water demanding garden, a tendency also observed in the U.S. (Osmond and Hardy 2004, Sovocool et al. 2006, Harlan et al. 2009, Polebitski and Palmer 2010). Nevertheless, there may be a maximum level of income at which water consumption is maintained despite an increase in wealth (Flörke and Alcamo 2009). The influence of the proportion of the household that does not work on potential water requirements in gardens may reflect the high proportion of retired people. They might own more water demanding gardens as they have more time to maintain them. Despite the above significant relationships between potential water requirements as judged by garden composition and socio-economic attributes, the level of explanation from these variables was extremely low.

Overall, our results suggest that other factors may be more important than those we measured, and that it is this variation that is directly influencing the nature and water needs of gardens. However, Aitken et al. (1994) suggest that attitudes expressed towards water conservation do not always represent the amount of water consumed. Other factors such as the effect of local policies, the pricing of water, the presence of professional water managers or even the legacy of urban developers, might also shape private landscape structure and therefore water needs. In this regard, multiple strategies, such as education through water-conservation campaigns, an increase of water pricing or water-saving regulations, should be adopted to curb domestic water demand (De Oliver 1999, Barrett 2004).

4.3. Limitations

Use of LWR as a proxy for actual water use levels should be considered a conservative estimation technique as empirical studies have showed that actual irrigation behavior in domestic gardens is independent of actual net irrigation requirements (Wentz and Gober 2007, Endter-Wada et al. 2008, Salvador et al. 2011). Due to the particularities of each garden and a lack of standard methods for estimating parameters, such as irrigation efficiency, deviations of LWR from real garden water use must occur.

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5. Conclusions

The results presented in this paper show that Spanish Mediterranean gardens are highly biologically diverse. The main floristic gradients of this landscape vegetation correlate to the socio-economic level of the household, highlighting the relevance of including this type of information when assessing landscaping patterns and therefore outdoor water demand. Our characterization of garden typologies (semi-natural, vegetable, lawn and ornamental) may give urban planners and water managers a starting point from which they can detect gaps in water management and determine those homeowners who could be targeted for water conservation education. This information may be critical in a context where global climatic change may exacerbate water scarcity, especially during the summer, and a large heterogeneity in garden types is found. Specifically, our findings suggest that there is price elasticity in demand for water among all except householders with vegetable gardens. There is therefore potential for reducing water demand among most of those with higher purchasing power by increasing prices. However, such a price increase would be at the cost of disadvantaging the poorer local residents who grow their own food. A socially and environmentally more desirable option may be strategic regulation of use. Prohibition of the use of water on lawns during summer months and restriction of other watering to hand held devices in early morning or late evenings are strategies that have proven effective in conserving water in drought-prone Australian cities (QWC 2013). The water-profligate Catalanian lawn gardener may be encouraged to switch their mesic lawn...
to other lawn types with lower water requirements. Those with ornamental and semi-natural gardens will be encouraged to shift their garden species composition to emphasize more xeric plants, or to store rainwater on-site to irrigate more mesic plants. At the least, these actions would limit demand for additional water.

If education were to be adopted as the main strategy for Catalanian water conservation, our results suggest that it should be targeted at the wealthier permanent residents with lawn gardens. In this regard, future research should assess the predisposition of homeowners to modify their gardens and the relevance of water-conservation attitudes and behaviors to this preparedness. Finally, further collaboration between local governments, real estate companies and professional landscapers is required to promote water-sustainable urban landscapes in the Mediterranean region.

**Funding**

This work was supported by the Spanish Ministry of Economy and Competitiveness: (CSO2010-17488; FPI BES-2011-046475).

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