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Comparison of the economic value of urban trees through surveys with photographs in two seasons

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Abstract: Urban trees are generally considered to be a public asset and are an important part of a city's heritage. The aim of this work is to analyse the influence of season on the economic appraisal of various trees in Madrid. Photographs were taken of 43 individual tree specimens in summer and winter. The survey was designed to compare differences of opinion in the economic assessment of trees. The trees were assessed by five valuation methods used worldwide. 78 agroforestry engineering students answered a written survey, and the variables considered were: percentage of students who always evaluated the tree equally (%0), percentage of students who assigned more value to the summer photograph (%S), and percentage of students who assigned more value to the winter photograph (%W). The results were analysed by the statistical test of equal proportions and ANOVA to detect differences according to tree type (evergreen or deciduous), species and other groupings made by the authors in previous works. W and S percentages are similar. The ANOVA analysis rejects the equality of percentages of S and W between groups. The Welch test rejects the equality of percentage of S, W and O between species.

Keywords: appraisal; urban trees; public opinion; photography; summer-winter.

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1. Introduction

The economic value of urban trees is a monetary reference for the benefits they offer the public. It reflects a variety of factors such as the value of the land where the trees are located, their historic importance, quality and state of health, the social and environmental benefits they afford, and the costs associated to their maintenance.

These economic values are obtained from assessment equations or formulas that consider –with greater or lesser weight– a combination of the above mentioned factors. The appraisal of urban trees is not an exact science, as it depends on the purposes of the assessment and the assessor's experience [1,2]. Each method or formulation takes different variables into account and provides different results. Numerous methods are used to evaluate urban trees in different regions of the world, and most define the value in monetary terms based on an expert's perception of the tree. The assessment involves establishing a measurable and objective criterion considering aspects or variables such as whether the tree stands alone or in a group, its physical deterioration, species and variety, size, age,

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state of health and location, among others [3], along with environmental, social and psychological variables [4].

The assessment can therefore be used as one of the bases for decision-making about the management of these trees and as an instrument for public administration and for society itself. So what is the most appropriate method for assessing urban trees in a particular city?

To answer this question, several authors have conducted studies comparing methods for appraising urban trees. The valuation methods used show important differences [5-10] It is concluded that no method can be used under all conditions [1] and it is recommended to combine capitalization and parametric methods [11]. There is therefore no simple solution to the question, and each method must be applied after an exhaustive study of multiple factors including the availability of reliable databases, the proposal of objects for assessment and possible social repercussions.

This is where the aim of the assessment can be directed towards seeking a method that is closely aligned with social perception. What percentage of the population would choose one method as being the most closely aligned with reality? The answer necessarily involves conducting a survey of the public.

The survey technique is frequently used in issues related to the urban environment for the purposes of territorial management and planning, and the results serve to outline the managers' future lines of action. Different works show the concern to evaluate the opinion of the public, for example, for question the effects of biodiversity on the perception of urban green spaces [12], the risk of urban trees at the municipal level is evaluated through surveys to residents [13]; other studies evaluate the urban forest factors that citizens consider to be the most beneficial [14] or their recreational preferences [15]. Citizens are also consulted at the level of prevention to assess their reactions to the negative effects of urban trees in the specific case of a storm [16]. In all cases, the knowledge of citizens' opinions allows future actions to be planned for managing the environment and can be used to select indicators for establishing new urban forests [17]. However, there are no studies that compare different appraisals with evaluation methods that consider citizens' opinions or perceptions on this subject.

It is precisely the aim of this study to assess this aspect. The tool chosen was the photographic survey. Most studies show that photographs can be used as a valid substitute for aesthetic judgements [18-21]. Other authors have verified the validity of photographs to assess not only aesthetic but also biological aspects, like the study which suggests the validity of photo-based scenic beauty assessments [22]; group averaged on-site and photo-based assessments were very similar. The repeat photography is applied in different works and found it to be an efficient, effective and useful method to identify region-wide trends in land-use change [23]; provides a reliable and consistent measurement of phenophase in to monitored plant phenology [24]. Similarly, is showed that digital photography is useful for observing the seasonal change in aboveground green biomass and foliage phenology [25]. Is demonstrated that the use of photography to evaluate the perception of forest vegetation and management in urban woodlands can serve as a useful quantitative method and a complement to conventional methods [26]. Last year similar results were revealed using new technologies, to compared landscapes in Devon (UK) and Asturias (Spain) through on-site visits and images taken by UAV (unmanned aerial vehicles), revealing a high degree of consensus between

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both assessments [27]. Applying the same technology, is used UAV to measure within-season tree height growth in a mixed forest stand, and found that the results closely agree with published field observations for four tree species [28]. However, the photographic survey with images of trees may be conditioned by the season of the year in which the photographs are taken.

The aim of the present study is to conduct surveys of a population group using photographs of different trees to determine whether there are statistically significant differences in the assessment of the specimens depending on the season of the year in which the photographs are taken.

2. Materials and Methods

2.1. Study area

The study took place in the Forestry and Environmental Engineering School at the Madrid Polytechnic University in Ciudad Universitaria (Madrid). It has an area of 8.57 ha, of which 7.62 ha are forested. This green space was designed to meet two requirements: to contribute to the regeneration of the forest in the Ciudad Universitaria and to show students the forest species of most interest. One characteristic feature of this space is that it has a high diversity. There are 2,978 individuals in the arboretum inventory, corresponding to 129 different tree species [7].

2.2. Survey design

The survey was designed to compare the differences in opinion expressed by the public in regard to the economic value of the specimens, and the influence of the season on this appraisal. The respondents were shown photographs of 42 tree specimens belonging to 12 species. The photographs were taken with a digital camera (Canon EOS 450D, 18-55 mm) from the same point of view and by the same person in two different seasons: one in June, which we call the summer photo (S); and another in December, which we call the winter photo (W).

Of the 42 specimens selected, 27 are evergreen species and 15 are deciduous. The 42 trees were divided into four groups based on other characteristics [see 7], as follows: Freq group (most abundant species in the city of Madrid, 21 specimens); Max group (species with the greatest economic value in all the methods analysed, 7 specimens); Min group (species with the lowest economic value in all the methods analysed, 7 specimens) and Sin group (species considered as singular trees, 7 specimens).

Table 1 shows the selected species and the number of specimens, in addition to the leaf type and the group to which they belong.

Table 1. Specimens selected in the study grouped by their factors.

Species(SP)	Leaf type (Type)	Group	Number of specimens
Cupressus arizonica Greene	perennial	freq	7
Pinus pinea L.	perennial	freq	7
Platanus x *hybrida* Brot.	deciduous	freq	7
Quercus suber L.	perennial	max	7
Ailanthus altissima (Mill.) Swingle	deciduous	min	7
Cedrus deodara (Roxb.) G.Don	perennial	Sin	1

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Pinus halepensis Mill.	perennial	Sin	1
Chamaerops humilis L.	perennial	Sin	1
Eucalyptus globulus Labill.	perennial	Sin	1
Populus alba var. *bolleana* (Lauche) Otto	deciduous	Sin	1
[1]*Quercus canariensis* Willd.	perennial	Sin	1
Sequoiadendron giganteum (Lindl.) J.Buchholz	deciduous	Sin	1

[1] The species Quercus canariensis has marcescent leaves but has been classified for the statistical analysis as evergreen, as there are no observable differences between the summer (S) and winter photographs (W).

2.3. Appraisal methods used

The tree specimens selected were appraised by eight valuation methods used in different parts of the world. These methods are classified in three types according to their formulation: parametric, mixed and capitalisation [see 29].

2.3.1. Parametric methods

- North American method (CTLA). It defines the "base value" as the expression of the nursery's unit price according to the cross-section of the trunk, and uses corrective indexes to maintain or reduce its value, but never to increase it.
- Burnley method (Burnley). Its main variable is the tree size measured as the volume of an inverted cone, considering the height and crown area. It also includes a monetary value, designated "base value". The final figure may be modified by factors that can reduce the base value. This is used mainly in Australia [30].
- Formulaic Expert Method (FEM). This method selects six main criteria (dimension, species, individual, state, location and outstanding consideration), and the monetary value of the tree is the result of multiplying the total score of the main criteria of a tree by a monetary assignment factor (MAF) derived from the three-year average sales price per square meter of a mid-sized residential home. Used for singular trees in Hong-Kong.
- Copima method (Copima). This is based on the price of the species in the local market, corrected by multiplicative indexes that increase the value of the specimen. It is used in the municipalities of Concepción, La Pintana and Maipú (Chile) [2].

2.3.2. Mixed methods.

- Granada standard (N. G.). In the first versions of this method the base value was obtained for each species with a regression model based on the tree age. Since the last review, the method uses the trunk circumference measurement (measured 1 m from the ground) modified by intrinsic and extrinsic factors. It is used in Spain.
- Contato method (Contato). This classifies the trees based on their diameter, height and crown area. The base value of each tree is calculated according to its age using the capitalisation formula, and is modified with corrective multiplicative factors that can increase or decrease the end value. Used in Argentina.
- New Zealand method (Standard Tree Evaluation Method) (STEM). This is one of the most widely used methods, and applies a system of points to assess 20 tree attributes in three general categories: state, functions and outstanding qualities (special merit). The total score (P, with a maximum of 540 points) is multiplied by the wholesale cost of a five-year-old tree (without a

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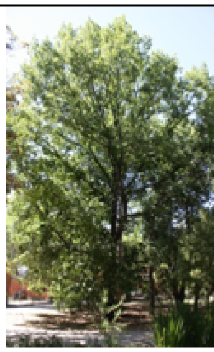
specific indication of the tree species). To this is added the wholesale cost of planting and maintaining the tree until it reaches the same age as the replaced specimen.

2.3.3. Capitalisation methods.

- Capitalisation method (Capitalis.). This is based on the capitalisation of the replacement and maintenance costs throughout the life of the tree. Two methodologies can be distinguished. The first uses the replacement costs, and involves finding specimens of the same species, age and physical and ornamental characteristics on the market, and whose transplantation is technically feasible. This tree must also have a high possibility of rooting without compromising its normal development.
  The second is based on maintenance costs, assuming that the tree chosen to replace the tree being appraised is younger. That is, it is estimated that the internal yield rate (r) for transforming the future tree into the current tree represents an intermediate situation where the substitute tree has a somewhat lower age and dimensions than those of the current tree.

2.4. Conducting the survey

The survey consisted of five pages of DIN A4 (210x297 mm) paper; the first page contained questions on personal details such as sex and age range (18-30, 30-45, 45-60 or over 60). The following pages included a photograph of each specimen with an identification number, and, on the right, the valuation options in euros obtained with the different methods ordered from lower to higher. The first survey was made in May (with the photos we have called summer), and a second survey in October, with the winter photos. Figure 1 contains an example of the three specimens showing the photographs of both seasons together.

ID: 10	Valor (€)	ID: 321	Valor (€)	ID: 358	Valor (€)
	47 112 119 304 499 809 84.264 177.601		2.825 3.570 8.757 12.766 15.407 18.900 79.071 989.904		5.832 7.258 14.845 53.917 83.762 104.848 175.116 2.424.146

(a) Summer photographs

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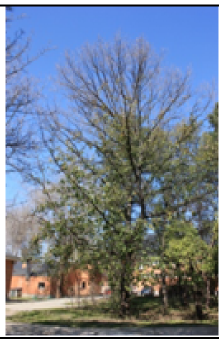
ID: 10	Valor (€)	ID: 321	Valor (€)	ID: 358	Valor (€)
	47 112 119 304 499 809 84.264 177.601		2.825 3.570 8.757 12.766 15.407 18.900 79.071 989.904		5.832 7.258 14.845 53.917 83.762 104.848 175.116 2.424.146

(b) Winter photographs

Figure 1. View of the survey with three of the specimens presented for evaluation through photographs taken in summer (S) (a) and winter (W) (b).

The respondents were students of the Forestry Engineering degree (first year) and the Master's degree in Forestry Engineering at the School of Forestry and Environmental Engineering at the Madrid Polytechnic University. The opinion of a total of 78 students was collected.

2.5. Statistical methods

The data from the completed surveys were entered in a MS Excel database (2010) for their subsequent statistical processing with the STATGRAPHICS Centurion XVII software (2014).

The variables used were: proportion of students who assigned the same economic value to the same specimen in both seasons (%0), proportion of students who assigned more value to the winter photograph (%W), and proportion of students who assigned more value to the summer photograph (%S).

Two statistical analyses were performed: the t test for paired samples, comparing the three above-mentioned variables for each specimen. The null hypothesis was that the proportions were equal. The hypothesis of normality was also verified with the Shapiro-Wilk test.

The valuations for the three variables were compared with a simple ANOVA, and box plots were obtained. The factors were species, leaf type and group. The null hypothesis was the equality of proportions for the different factor levels (SP, Type, Group). The equality of variances between factor levels was verified with Levene's test. In the case of the SP factor, in which only one specimen was valued for some species, the robust Welch test was used with a null hypothesis that was equal to equal mean proportions. This test assumes the inequality of variances; it is adequate when the number of specimens differs widely between factor levels, and the sample sizes are small [31]. The levels with statistically significant differences were obtained using the multiple range test with limits by Fisher's LSD (Least Square Differences).

A significance level of 5% was used in all the statistical tests.

3. Results

The survey was given to 40 undergraduate and 38 Master's degree students, of whom 27 were women and 51 men.

The answers were grouped as follows: number of students who left some valuation unanswered (Unanswered); number of students who chose a method with more value in the

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summer photos (S); number of students who chose the same value (0) in both stations (S and W) and number of students who chose a method with more value in the winter photos (W).

The pie chart in Figure 2 shows that the number of students who assigned a greater value to the specimens in the S photos (36%) is very similar to the number of students who assigned more value to the specimens in the W photos (34%). 28% of the students assigned the same value, and only 2% of cases had photos with no valuation.

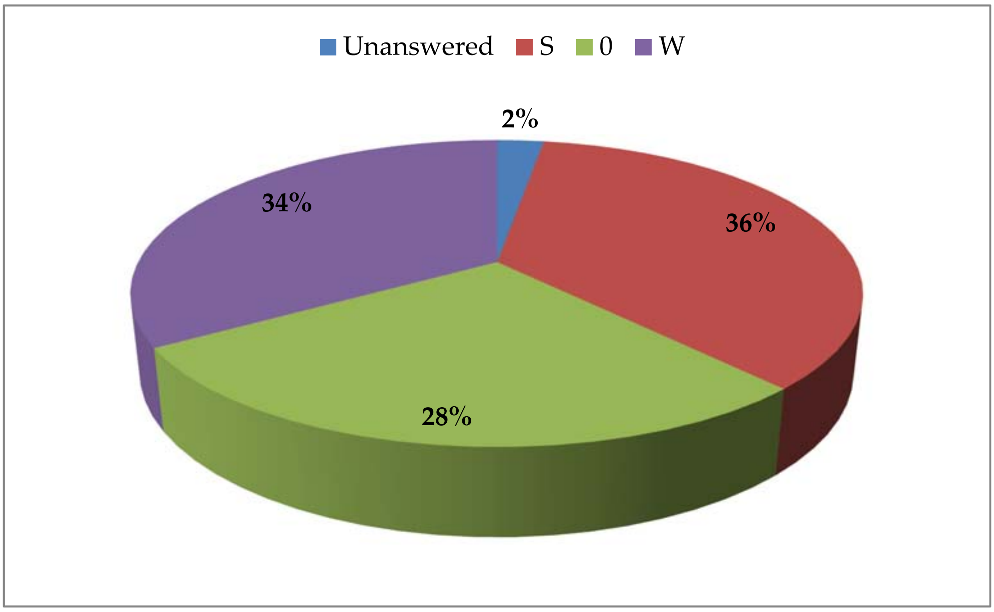

Figure 2. Percentage of students according to the differences shown in the valuation.

The hypothesis that the three variables considered (%S, %0 and %W) have a normal distribution cannot be rejected (Shapiro-Wilk test with p-value > 0.05). Table 2 contains a descriptive summary of these variables.

Table 2. Descriptive statistics of the variables

Statistical	%S	%0	%W
Minimum	20.5	16.7	20.5
Maximum	50	39.7	52.6
Mean	35.6	28.1	33.8
SD	7.37	5.65	8.08
CV	20.70%	20.06%	23.93%

[1] SD standard deviation, CV coefficient of variation

Similar values can be seen in regard to the measures of variability (SD and CV). The mean values show the lowest value for respondents who rate the photos equally and the highest for those who rate the summer photos higher.

Student's t test was done for the paired samples of percentages calculated in the same tree as shown in Table 3.

Table 3. t-test results

Null hypothesis	Alternative hypothesis	p-value	Estimated mean difference
%0 = %S	%0 < %S	0.000021	7.5%

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%0 = %W	%0 < %W	0.001457	5.5%
%S = %W	%S > %W	0.198641	1.8%

The results of Table 3 show:

- Significant differences between "percentage of students who rate the specimen more highly in summer" (% 0); the difference in percentage is estimated at 7.5%, in favour of %S.
- Significant differences between "percentage of students who rate the specimen more highly in winter" (%W) and "percentage of students who rate the specimens the same in both seasons" (%0); the difference in percentage is estimated at 5.6% in favour of %W.
- Finally, no significant differences are observed between %S and %W.

A simple ANOVA (Table 4) is done to analyse the possible influence in each proportion variable (%S, %0 and %W) of the species (SP), leaf type (Type) and group factors (Group) defined in Table 1.

Table 4. ANOVA results (p-value)

Factor	**%S**	**%0**	**%W**
SP	0.0881	0.7097	0.1572
Type	0.2151	0.9849	0.2102
Group	0.0248	0.9726	0.0166

The results of Table 4 show that for the survey data:

- there is no influence of the Type factor in any of the percentage variables;
- there is no influence of the SP factor in the classes %0 and %W; or in %S for a level of 0.05.
- there is no influence of the Group factor in %S;
- there is a possible influence of the SP factor in %S at a 10% significance level;
- there is a possible influence of the Group factor in %S and %W at a 5% significance level.

The graphs in Figures 3 and 4 show the distribution of the values of the variables %S and %W according to the Group factor levels with statistically significant differences in the ANOVA test (Table 4).

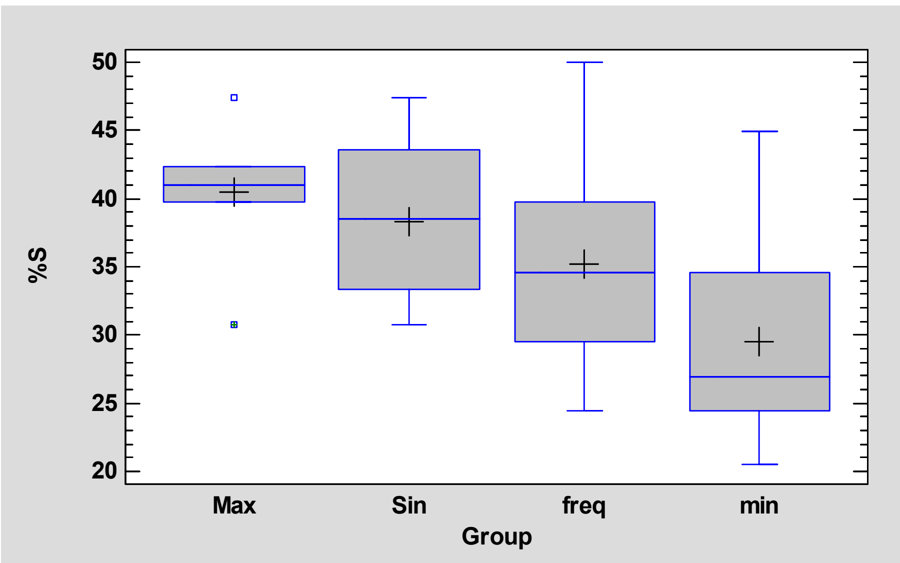

Figure 3. Box chart for %S according to Group.

Figure 3 shows that the specimens that scored highest in all the methods were also rated more highly in the S photos by more students.

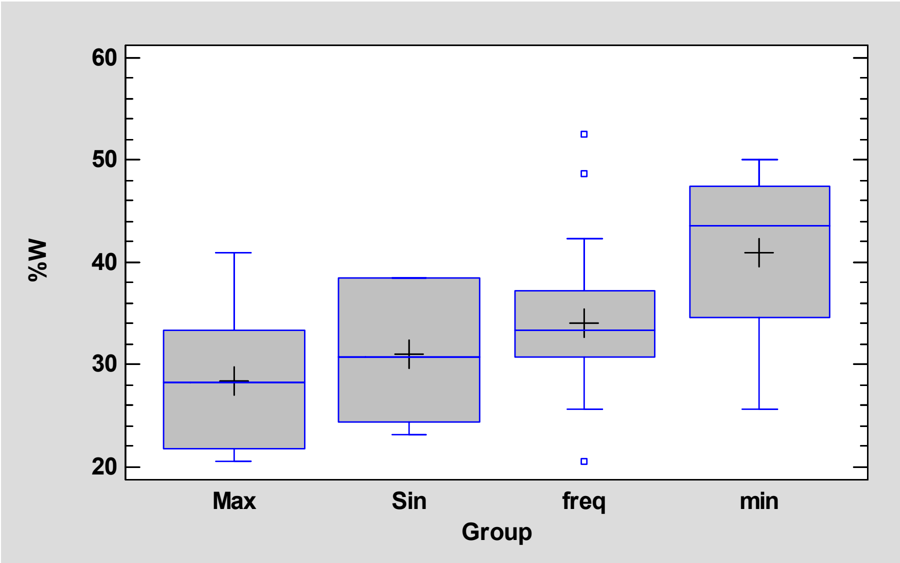

Figure 4. Box chart for %W according to Group.

Figure 4 show that the specimens with the lowest scores in all the methods (min) had a higher average %W than the rest.

Tables 5 and 6 show the comparisons by pairs of levels for the Group factor for the variables %S and %W.

Table 5. Significant results to 95% of the multiple range test (LSD) for %S according to Group.

Comparison of Groups	Differences
Max - min	10.9714
S-min	8.78571

Table 5 shows that the average of %S is significantly lower for specimens with lower economic valuations in all the methods than for the group of maximum valuations and the group of singular trees.

Table 6. Significant results to 95% of the multiple range test (LSD) for %W according to Group

Comparison of Groups	Differences
Max - min	-12.6286
S - min	-10.0286
freq - min	-6.98247

Table 6 shows that the average of %W is significantly higher for the specimens with lower economic valuations in all the methods than for the rest of the Groups.

The equalities of variance were verified for all the ANOVA analyses with the Levene test to a confidence level of 95%. This equality was not rejected for Type and for Group, but could not be accepted for SP in any of the % variables. The box chart in Figure 5 illustrates these differences in the dispersion of the groups of %S. This graph shows that due to the different sample size of %S according to the SP factor levels, there is homogeneity of variances, which invalidates the ANOVA for this factor.

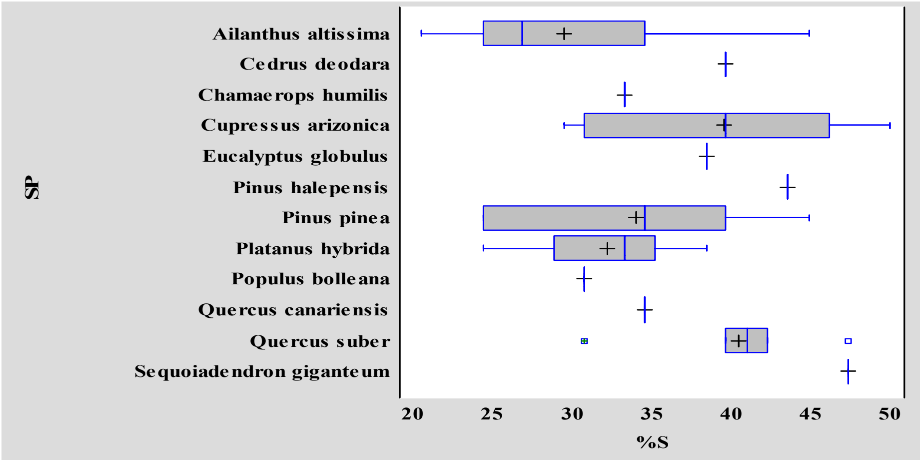

Figure 5. Box chart for %S according to species.

The equality between the medians of each variable of % between levels of the SP factor can be rejected with the Welch test (Table 7).

Table 7. Results of the Welch test for the SP factor (p-value)

%S	%0	%W
0.0001	0.0001	0.0001

Multiple comparisons are made between %S values by SP pairs resulting in significant differences, as shown in Table 8. The results with the same tests were done for the variable %0 (Table 9) and %W (Table 10).

Table 8. Significant results of the multiple range test (LSD) for %S according to SP.

Comparison of SP	Difference
Ailanthus altissima - Cupressus arizonica	-10.0857
Ailanthus altissima - Quercus suber	-10.9714
Ailanthus altissima - Sequoiadendron giganteum	-17.9143
Cupressus arizonica - Platanus x *hybrida*	7.34643
Platanus x *hybrida - Quercus suber*	-8.23214
Platanus x *hybrida - Sequoiadendron giganteum*	-15.1750

Comparison of SP shows the SP pair in which the differences in %S are valued.

Difference is the value of the difference in percentage, with negative values when the percentage variable is greater in the second species in the pair and positive otherwise.

Table 8 shows that the median of %S for *Ailanthus altissima* is lower than for the species *Cupressus arizonica* (difference -), *Quercus suber* and *Sequoiadendron giganteum*. The median of %S is

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significantly higher for *Cupressus arizonica* than for *Platanus* x *hybrida*. The median of %S is significantly lower for *Platanus* x *hybrida* than for *Quercus suber* and *Sequoiadendron giganteum*.

Table 9. Significant results to 95% of the multiple range test (LSD) for %0 according to SP**.**

Difference in SP	Difference
Cedrus deodara - Chamaerops humilis	-17.9
Chamaerops humilis - Cupressus arizonica	12.9
Chamaerops humilis - Sequoiadendron giganteum	17.9

Table 9 shows that the median of %0 for *Chamaerops humilis* is lower than for the species *Cedrus deodara, Cupressus arizonica* and *Sequoiadendron giganteum.*

Table 10. Significant results to 95% of the multiple range test (LSD) for %W according to SP

Difference in SP	Difference
Ailanthus altissima - Chamaerops humilis	16.6143
Ailanthus altissima - Cupressus arizonica	9.88571
Ailanthus altissima - Pinus halepensis	17.9143
Ailanthus altissima - Quercus suber	12.6286
Platanus x *hybrida - Quercus suber*	8.63929

The results of Table 10 show that the median of %W for *Ailanthus altissima* is higher than for the species *Chamaerops humilis*, *Cupressus arizonica*, *Pinus halepensis* and *Quercus suber*. The mean of %W is significantly greater for *Platanus* x *hybrida* than for *Quercus suber*.

4. Discussion and Conclusions

Authors should discuss the results and how they can be interpreted in perspective of previous studies and of the working hypotheses. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted.

The results show that a similar proportion of students award the highest value to the specimen photographed in summer (%S=36) and in winter (%W=34) without any significant differences. The %0 percentage is not very different from the previous ones, but in this case there are significant differences. The CV is similar in all three cases.

The ANOVA analysis reveals significant differences between the Groups of trees for the percentage of students who value the summer trees more highly, and for the percentage who value the winter trees more highly. However, there are no differences between Groups for the respondents who value the specimens equally.

The group of trees with the lowest scores in all the methods are the specimens of *Ailanthus altissima*. The ailanthus has the highest percentage of students who value the trees more highly in the winter photos. These are in turn the specimens with the lowest percentage of students who assess the summer trees more highly. This may be due to the fact that they are mostly young specimens that shed their leaves in winter, which may improve their valuation when comparing them with other specimens with deciduous leaves at this time of year. In any case, this is still an unverified supposition.

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The opposite occurs with *Quercus suber*. These trees achieve higher scores with all methods. Cork oaks have the highest percentage of students who rate the summer trees more highly. These are also the specimens with the lowest percentage of students who rate the winter trees more highly.

There are no differences for the factors considered among the students who rated the specimens in the winter and summer photos the same. The data in this work offers no explanation for this result, which was also obtained in a previous work by the authors [32].

Likewise, it is worth highlighting the lack of any significant differences between the specimens with perennial and deciduous leaves for any of the groups of students. This result contradicts the authors' result in a previous study [32], possibly due to the student sample, which consisted of more undergraduate than Master's students, and where there was an imbalance in their knowledge of trees. On this occasion the sample is balanced between both. Differences in educational level affect the respondents' preferences, as can be concluded from other works [33,34]. These differences can even be seen between university students with different educational levels [35].

Differences between species were detected with the Welch test for the three groups of students. In the first group (%S), a lower percentage of students value the ailanthus trees more highly in the summer photos than cypress, cork oak and sequoia trees. Plane trees have a lower percentage of students who rate the trees more highly in the summer photos than cypress, cork oak and sequoia trees. The rest of the species do not show any significant differences.

In the group of students who assess the trees equally (%0), fan palms have a higher percentage of students than cedar, cypress and sequoia trees. That is, fan palms have more similar scores in both seasons of the year.

In the last group of students (%W) the ailanthus has the highest percentage of students who value the trees more in the winter photos than cypress, cork oak, fan palm and Aleppo pine. Plane trees have a higher percentage of students who value the trees more in winter photos than the cork oak.

These results do not point to any clear conclusions in regard to the differences in valuation between the seasons. The percentages of students are similarly distributed between the three options. It would therefore be advisable to increase the number of specimens per species and to make comparisons between groups that are internally more homogeneous. To verify the results between evergreen and deciduous trees, a study should be designed based solely on that factor with fewer photos. It is also necessary to increase the number of answers and maintain a balance between different educational levels. Clearer results can be obtained if the number of valuation methods is reduced.

Author Contributions: M. Ángeles Grande-Ortíz y Esperanza Ayuga-Téllez conceived and designed the experiments; Claudia García-Ventura and Álvaro Sánchez-Medina performed the experiments; Concepción González-García y Esperanza Ayuga-Téllez analyzed the data; Claudia García-Ventura wrote the paper.

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