International Conference of Agricultural Engineering
AgEng 2014 Zurich 6–10 July
Ref: C0615

Comparison of three valuation methods for three tree species at the Arboretum of the Forestry Engineers School (Madrid)

Claudia García-Ventura. Escuela Técnica Superior de Ingenieros de Montes. Universidad Politécnica de Madrid. Ciudad Universitaria s/n. 28040 – Madrid. cgventura1@gmail.com

Esperanza Ayuga-Téllez. Buildings, Infrastructures and Projects for Rural and Environmental Engineering (BIPREE). Escuela Técnica Superior de Ingenieros de Montes. Universidad Politécnica de Madrid. Ciudad Universitaria s/n. 28040 – Madrid. esperanza.ayuga@upm.es

Mª Ángeles Grande-Ortíz. Sustainable Management. Escuela Técnica Superior de Ingenieros de Montes. Universidad Politécnica de Madrid. Ciudad Universitaria s/n. 28040 – Madrid. m.angeles.grande@upm.es

Álvaro Sánchez de Medina. Buildings, Infrastructures and Projects for Rural and Environmental Engineering (BIPREE). Escuela Técnica Superior de Ingenieros de Montes. Universidad Politécnica de Madrid. Ciudad Universitaria s/n. 28040 – Madrid. alvaro.sanchezdemedina@upm.es

Abstract

The presented work compares three valuation methods in three tree species of the Arboretum of the Madrid Forestry Engineering School, and is framed in a bigger project of comparison methods of valuation for this Institution. For this study three species with different characteristics were selected and three valuation methods were applied in 43 individuals selected through a species sample. The selected species are some of the most common in Madrid: *Ailanthus altissima* (Mill.) Swingle, *Platanus hybrida* Brot. and *Cedrus atlantica* (Endl) Carrière. The valuation methods employed are: the "American method" of the Council of Tree Landscape Appraisers (CTLA) (CTLA 2000), Norma Granada (NG) (AEPJP 2007) and Capitalization methods (ECM) (Caballer 1999). The sample selection was performed using a species systematic sampling of the individuals, based on the standard deviation of the Diameter at breast hight (Dbh) with an error limit of 5 centimeters and a confidence level of 95%. The comparison of the results has been done with the t- test for paired samples and an ANOVA with species factor and valuation method, with a confidence level of 95%. The results for the standardized variables show no statistically significant differences between methods, and show statistically significant differences between species and also in the interaction of method and species. In the analysis of non-standardized variables, differences between methods, species and the interaction between them were found. The highest valuations were obtained with the NG and ECM methods, and the lowest valuations come from the CTLA method.

Keywords: tree appraisal, statistical analysis, urban forestry, urban forest.

1 Introduction

Urban tree is a component of the landscape of cities. It brings many benefits to both landscape and citizens, whenever they are under proper management. The latter should be

guided by economic and biological criteria. The methods of valuation of urban trees are those that give management guide for proper management.
Valuing inserts spaces in cities, as an intangible, based on economic criteria and keeping the singularities of the tree-covered is currently been studied without standardized criteria (Grande-Ortiz et al., 2012).
Valuation methods of urban trees provides an economic or monetary reference to citizens. They should also reflect other factors such as land value, quality, social and environmental benefits and costs involving on maintenance where they are located. Therefore, the valuation should be one of the bases to be used for making decisions in management.
Several authors have carried out studies comparing valuation methods urban trees. Watson (2002) and Ponce et al. (2009) used, among others, in their studies, the same methods as in this. In a line similar to the above can highlight the work of Hegedüs et al. (2011). More recently, López and López (2013) and García-Ventura (2013) makes a comparison between different types of valuation methods, parametric and economical
The objectives of this study are:
• To compare the results of three valuation methods in a sample of trees, from the Arboretum of the Forestry Engineer School.
• To study whether differences were found between methods, valued species and if there is influence of the combination.
• Discuss the most significant features of both methods and their adaptation to the valuation of this green-space..

2 Materials and methods

2.1. Study area

The construction of the School of Forest Engineering in the University City (Madrid) took place between 1942 and fall 1945. The original project included complementary services, especially the idea “to surround the school with an appropriated environment, creating a park that constitutes the real laboratory of the School”. The execution of the project was directed by Luis Ceballos. The School campus has an area of 8.57 ha and tree covers up to 7.62 ha (Navio 2003).
At the arboretum, 2978 individuals of 129 different tree species in 45 different areas and surface composition have been inventoried (Pérez 2013).
That park or green space designed met two requirements: contribute to the forestry regeneration of the University City and show to the students the forestry species of interest. This space has a high diversity, where 400 arboreal species has been inventoried. The Arboretum has three distinct areas:
1. Dense woodland with paths, with native forest tree species of interest.
2. Ornamental garden around the main building, with temperate species like olives and palms.
3. A zone dedicated to acclimatization and cultivation.

2.2. Selected species and variables

The selected species are some of the most common in the city of Madrid: *Ailanthus altissima* (Mill.) Swingle, *Platanus hybrida* Brot. and *Cedrus atlantica* (Endl) Carrière.
The measured variables in the sample trees were:

- Diameter at breast height: *Dbh* (cm). It is measured on the trunk, with bark, at a height of 1.30 m above ground level. From this measurement the perimeter (*p*) of the trunk was obtained like a circumference.
- Height: *h* (m). Distance between the trunk base and the top end of the crown, measured on its axis.
- Crown area: *ca* (m^2). Considered the crown width, the projection on the ground surface in m^2, two measures were taken, the longest and its perpendicular (Thren

1993); (Diéguez et al. 2003). The crown area was estimated like the rhomboid area formed by the two measurements (Figure 1).

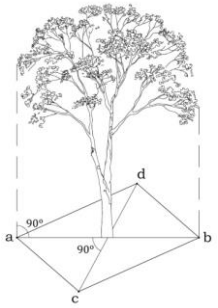


Figure 1: Calculation of crown area

- Age: *t* (years). Calculated using the equation of linear regression model based on data from urban forestry of Santiago del Estero (Ayuga-Téllez et al., 2007).

$$t = 0{,}701774p + 0{,}368309h - 0{,}0295051ca \quad [1]$$

2.3 Valuation methods

The different appraisal methods have traditionally been classified into three groups(Contato-Carol, 2004; López and López 2013): multiplicative or parametric methods, economic or capitalization methods and mixed methods. In this work we employed two mixed methods (Norma Granada and CTLA) and a capitalization one (ECM). These are defined as follow:

2.3.1 The Norma Granada (NG) method (AEPJP, 2007)

In early versions of this mixed method the based value was obtained for each species trough a regression model based on tree age. The last revision of the method uses the following expression for valuating a tree:

$$Value = (Bv \times Els)\,(1+Ele) \quad [2]$$

Where *Value* is the final value; *Bv* is the basic value obtained for each species in a regression model based on circumference (1 m from the ground); *Els* is the value for health and photosynthetic activity; *Ele* represents extrinsic factors (aesthetic appeal and function, representation and rarity value, location and other exceptional factors). Obtaining these values implies a comprehensive data collection in the tree to be appraising.

2.3.2 The Council of Tree and Landscape Appraisers (CTLA) method (CTLA, 2000)

This method give rise to the idea of a “basic value” as an expression of the unit price of a section of trunk, and considers the maximum value of a tree to be the product of this basic value multiplied by the area of the section of the trunk. Corrector indices (species, condition and location) maintain or reduce this value, but never increase it.

$$\text{Value} = [\text{trunk area } (cm^2) \times \text{basic price per } cm^2] \times \text{species} \times \text{condition} \times \text{location} \quad [3]$$

This method only considers the utilitarian aspect of trees.

2.3.3 Capitalization method (ECM) (Caballer, 1999)

Capitalization method evaluates trees by applying indexes, matrix tables and other simplified forms, and is aimed at making the calculations easier for people who are not necessarily

experts in the subject. The interest rates are the rate of growth of the tree and the accumulated average annual growth rates distributed in different ways throughout the life of a tree.
There are two basic methods of capitalization: based on the replacement costs and based on maintenance costs (Caballer 1999).
The equation used as the basis for replacement cost methods is:

$$Value = P_r + (C_m \times k) + C_r \quad [4]$$

Where *Value* is the final value; P_r is the market price of the tree; C_m is the cost of annual maintenance; C_r is the cost of removal and k is the factor determined by the age of the tree.
The equation used as the basis for maintenance cost methods is:

$$Value = (1+i)^{t-t_0} (P_r + C_t)/P \quad [5]$$

Where *Value* is the final value; i is the interest rate; t-t_0 is the number of years during which maintenance tasks are performed; P_r is the market price; C_t is the planting costs and P is the probability of root.

2.4 Statistical methods (Ayuga-Téllez et al., 2013)

The sample selection was performed by using a systematic sampling of the inventory individuals by species, based on the standard deviation of the *Dbh* with an error limit of 5 cm with a confidence level of 95%. The description and statistical summary the variables measured in the sample trees was performed with STATGRAPHICS Centurion XVI.I.
Statistical values obtained were:

- Count: Number of trees of each species that are part of the sample.
- Average: arithmetic mean of the sampled individuals.
- S.D.: standard deviation.
- Min: the smallest sample value.
- Max: the largest sample value.
- C.V.: variation coefficient.
- r: Spearman correlation coefficient.

Multiple ANOVA test was performed to detect differences between mean values of the same variable (standardized economic value) for method, species and interaction between both factors. A significance level of 5% was used to detect statistically significant differences.
Test for differences in paired samples were also performed between methods. Results are expressed as the confidence intervals for the mean difference with a 95% level.

3 Results and discussion

The description of the sample contains average values and standard deviation for each variable. It is showed in Table 1.

Table 1: Description of the sample: mean and standard deviation of the variables.

SPECIES	n	AVERAGE VALUES				S.D. VALUES			
		***Dbh*(cm)**	***h* (m)**	***ca* (m^2)**	***t***	***Dbh*(cm)**	***h* (m)**	***ca* (m^2)**	**t**
Ailanthus altissima	7	20.5	10.4	24.5	48.7	6.7	2.3	16.1	15.3
Cedrus atlantica	22	28.6	14.5	16.6	68.7	8.1	2.6	8.4	18.1
Platanus hybrida	15	26.9	11.8	29.8	63.9	10.5	4.1	29.4	24.4

Statistical summary of the valuations obtained are shown in Table 2:

Table 2: Statistical summary of the valuations.

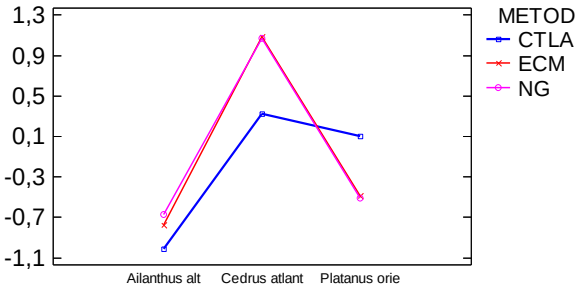
Statistical Value	***ECM***	***CTLA***	***NG***
Average	3021.45	203.19	2406.31
SD	2192.89	160.70	3213.36
CV	72.57%	79.09%	133.54%
Min	773.8	17.72	65.7
Max	9234.7	659.06	13245.8

When performing a Spearman correlation analysis for the sample data, the r values obtained are: r=0,6903 for NG and CTLA methods, r=0.9884 for NG and ECM, and r=0.6837 for CTLA and ECM, all of them with p-values equals 0. P-values less than 0,0001 indicates significantly different correlations between pairs of methods. High correlations between methods NG and CTLA is consistent with similar correlations of both with ECM. Also ECM correlation between the others methods is slightly lower.
The results comparison has done with the t- test for paired samples and an ANOVA with species factors and valuation method, with a confidence level of 95% (Table 3).

Table 3: ANOVA for factors and their interaction.

Source of Variation	***Sum of Squares***	***DF***	***Mean Square***	***F-ratio***	***P-Value***
PRINCIPAL FACTOR					
A:SP	50.4866	2	25.2433	46.24	0.0000
B:METHOD	0.50217	2	0.251085	0.46	0.6324
INTERACTION					
AB	11.3635	4	2.84088	5.20	0.0007
ERROR	67.1502	123	0.545937		
TOTAL	129.0	131			

These results show for the standardized variables no statistically significant difference between methods, but differences between species and the interaction of method and species were found. In the analysis of non-standardized variables, statistically differences between methods, species and the interaction between them were found.
In the following graphs the influence of the interaction (Fig. 2.a) and the difference between species (Fig. 2.b) obtained with a 95% interval Fisher LSD are shown.



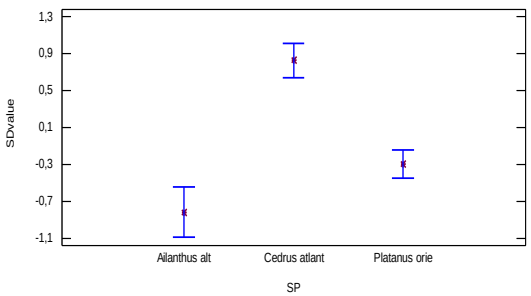


Figure 2.a: Interaction between method and species *Figure 2.b: Differences between species*

As it shows Figure 2.b *Cedrus atlantica* is the species with higher standarized values, and *Ailanthus altissima* the least valued.
Confidence intervals at 95% for the difference in valuations are: NG-CTLA: [1257,92; 3148,34]; NG-ECM: [-976,572; -253,7] and CTLA-ECM: [-3450,72; -2185,81]. These intervals show that it is not possible to accept the equality between methods when values are not

standarized, therefore that the basic values differ from one to another being ECM higher in average value than CTLA and NG, while NG values are greater than those of CTLA in the comparison of paired samples.
The following graph (Figure 3) shows the valuations obtained with each method for each individual of the sample. ECM and NG methods are those that provide higher valuations, while CTLA provides lower values with less differences between species as those that has been found in the t-test.

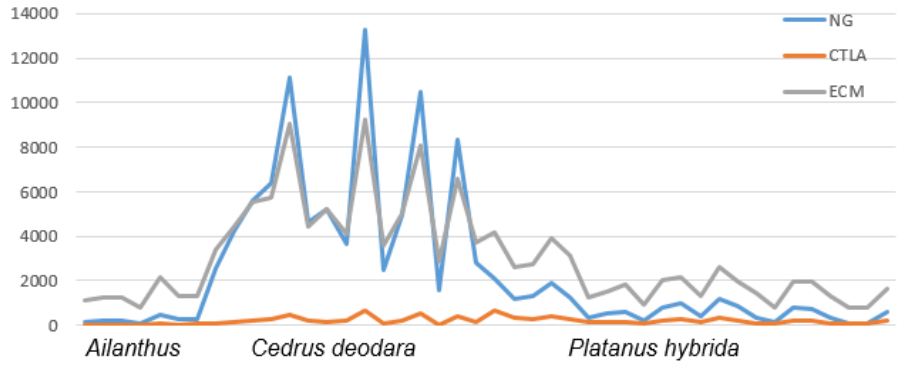


Figure 3: Valuation obtained for each species with each method.

4 Conclusions

- NG is a complete methosology and better adapted to the study area to be posed for the urban trees in Spain. It presents greater variability in the obtained valuations.
- CTLA is the method with lower values. Valuations from the three species are different although the species factor has less influence in CTLA method that in ECM and NG methods. In addition, CTLA presents more valuation differences with the other methods, more similar to each other. It may be due to the way of scoring this factor in the formula and the use of trunk in the basic value.
- If you do not have the age of the trees is preferable to use the NG method that ECM.
- ECM and NG methods provides similar values and similar values to all individuals. The species factor influences the value with ECM method.
- This result is remarkable because ECM is an economical method and not mixed as NG method.
- Given the results, NG is the method that gives the best value for the selected sample from the Arboretum of the Madrid Forestry Engineering School.

5 References

AEPJP (2007) Método para la valoración de árboles y arbustos ornamentales: Norma Granada: revisión 1999. *Asociación Española de Parques y Jardines Públicos*. Madrid.

Ayuga-Téllez, E.; Contato-Carol, M. L.; Grande-Ortiz, MªA.; González-García, C.(2007). Análisis multivariante para seleccionar las variables apropiadas para describir y valorar el arbolado urbano. Aplicación a Santiago del Estero (Argentina). *Resúmenes en Actas del IV Congreso Nacional y I Congreso Ibérico de Agroingeniería,* 232-234.

Ayuga-Téllez, E.; González, C.; Martín, S. and Martínez, J.E. (2013). Estadística: Guía Práctica y Ejercicios, *Ed. Fundación Conde del Valle de Salazar*, Madrid. 377pp

Caballer V. (1999). Valoración de árboles frutales, forestales medioambientales y ornamentales. *Ediciones Mundi-Prensa*, Madrid.

CTLA (2000). Guide for plant appraisal, 9ª Ed., Council of Tree and Landscape Appraisers, ISA, *Savoy*, IL. 143pp.

Contato-Carol, M.L. (2004). Análisis estadístico multivariante del arbolado urbano de Santiago del Estero (Argentina) y estimación de su valor mediante modelos econométricos. *Tesis Doctoral. E.T.S.I. de Montes*. U.P.M. 278 pp.

Diéguez Aranda, U., Barrio Anta, M., Castedo Dorado, F., Ruiz Gonzalez, A.M.,Alvarez Taboada, M.F., Alvarez Gonzalez, J.G., Rojo Alboreca, A., (2003).Dendrometría. *Coedición Fundación Conde del Valle Salazar, Ediciones MundiPrensa*. 327 pp.

García-Ventura, C.(2013). Comparación de métodos de valoración de arbolado urbano y su aplicación al Arboreto de la E.T.S.I. de Montes (Madrid). Proyecto Fin de Carrera *E.T.S.I. de Montes UPM.* Madrid.

Grande-Ortiz, M.A., Ayuga-Tellez, E. (2012). Methods of Tree Appraisal: A Review of Their Features and Application Possibilities. *Arboriculture and Urban Forestry nº38* (4). 130-140.

Hegedüs, A. Gaál, M. Bérces, R. (2011).Tree Appraisal Methods and their application; first results in one of Budapest's districts. *Applied Ecology and Environmental Research* 9(4): 411-423.

López Aguillón R. y López García M. 2013. Evaluación y comportamiento paisajístico de especies nativas en Linares, NL, 16 años de evaluación. *Revista Mexicana de Ciencias Forestales*, 4(17): 164-173.

Navio Abad, J. (2003). Proyecto de implantación de un sistema de riego y mantenimiento del arboreto de la E.T.S.I. Montes de Madrid. Proyecto Fin de Carrera. *E.T.S.I. Montes UPM*. Madrid.

Pérez Fernández, M. L. (2013). Catálogo vegetal del arboreto de la E.T.S.I. Montes: directrices para su conservación. Proyecto Fin de Carrera. *E.T.S.I. de Montes UPM.* Madrid.

Ponce Donoso, M.Piedrahita P. (2009).Valoración económica del arbolado urbano en 28 comunas de Chile. *Quebracho Vol.17 (1,2) 88-100*

Thren, Martín. (1993). Dasometría. Serie técnica Forestal. Vol. 1. Proyecto GTZ/UNSE. *Facultad de Cs. Forestales. UNSE*. 250 pp.

Watson, G. (2002): Comparing formula methods of tree appraisal. *Journal of Arboriculture* 28(1): 11-18.