Spanish Journal of Agricultural Research (2005) 3(1), 17-24

An application of the analytic hierarchy process method in farmland appraisal

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Abstract

This paper applies a multi-criteria methodology to farmland appraisal known as the analytic hierarchy process (AHP). This methodology is especially useful when there is partial information and/or qualitative variables are used or when quantitative variables are used but the professional does not have access to their quantification. This context presents difficulties when applying conventional farmland appraisal methods. Likewise, the application of the analytic hierarchy process to the field of farmland appraisal is an advance with respect to previous studies on the application of multi-criteria methods in which only quantitative variables have been used.

Additional key words: AHP, multi-criteria analysis, partial information, qualitative variables.

Resumen

Aplicación del proceso analítico jerárquico a la valoración agraria

En el presente trabajo se realiza una aplicación de la metodología multicriterio al caso de la valoración de fincas rústicas, concretamente del proceso analítico jerárquico (analytic hierarchy process, AHP), aplicación que resulta especialmente útil cuando la disponibilidad de datos es escasa y/o además se utilizan variables de tipo cualitativo o variables cuantitativas pero el experto no tiene acceso a su cuantificación, contexto en el cual ofrece dificultades la aplicación de los métodos convencionales de valoración agraria. Asimismo, la aplicación del AHP al campo de la valoración agraria supone un avance respecto a otros trabajos anteriores de aplicación de métodos multicriterio, en los que se utilizaban exclusivamente variables cuantitativas.

Palabras clave adicionales: AHP, análisis multicriterio, información escasa, variables cualitativas.

Introduction

Asset appraisal in general, and of farmland in particular, as a process with its own methodology, is based on the assets that are valued or appraised and which are located in a market that is very different from the perfect competitive model. Generally, this model does not perform well if applied to frequent transactions; although when it does perform well, it lacks transparency and is not homogenous, free and concurrent, and therefore the market value or probable prices cannot be easily estimated.

Conversely, information regarding market values is a fundamental element in the appraisal methodology and delimits the use of certain methodologies according to their database requirements. This allows for consideration of an ample array of possibilities which range from classic synthetic methods where the information is reduced to one reference value (Caballer, 1974; Ballestero and Romero, 1992), to modern developments in synthetic methods, Beta one-dimensional (Ballestero, 1973; Ballestero and Caballer, 1982; Alonso and Lozano, 1993; Garcia and Garcia, 2003) and two-dimensional methods (Romero, 1997; García *et al.*, 1999a,b; Palacios *et al.*, 2000; Herrerías Pleguezuelo *et al.*, 2001; 2002) to econometric methods (Caballer, 1976; Segura *et al.*, 1998; Calatrava and Cañero, 2000; Isakson, 2001) whose application requires a large amount of data and is therefore restrictive in the study of certain markets, despite being superior to previous methods.

In order to improve the results obtained by the development of comparative methods, the use of the multi-criteria methodology in the context of quantitative variables has already been proposed in previous works (Caballer and Aznar, 2004). The purpose of this paper was to take a further step in the

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Received: 24-03-04; Accepted: 01-12-04.

same direction by applying multi-criteria methodology, within a partial information context and when data are expressed with qualitative variables.

Methods (AHP)

This multi-criteria method, proposed by Saaty (1980) as a solution to specific decision making problems in the United States Department of Defence, is a classic in the commercial business world. It is applied in almost all settings where it is necessary to take decisions that reach a certain degree of complexity. Upon review of the records from the different international symposia on AHP that have been held to date, we find the method is applied in diverse areas such as education, transport, health and marketing. Nevertheless, despite the numerous applications of the AHP method, it has yet to be used in the area of farmland appraisal[1].

Potentially the method can be adapted to different situations. It is relatively easy to calculate using available software and can be used for both individual and group data[2].

The object of this paper is to propose and develop AHP for its application in farmland appraisal, especially in the situations described in the introduction, where only partial information is available, either due to the inaccessibility of direct quantification of the variables or because the explicative variables used are qualitative.

The adoption of this method over other discreet multi criteria methods, such as ELECTRE, widely used in decision making processes is because it works not only under the scenarios set out but also produces weighted results allowing its use in valuations. In relation to continuous multicriteria methods (Goal Programming, MOP, Compromise Programming, etc.,) some stand out as being very interesting for their use in valuation, and to the authors' knowledge there are Goal Programming applications in urban valuation by Caples *et al.* (1997) and agricultural valuation by Aznar and Guijarro (2005a,b). In both cases using quantified information, for the first two in a precise form and the latter in interval form.

Similarly, different authors attribute certain weaknesses to AHP such as the subjectivity of the procedure, the use of standardisation for the sum and the paired comparison scale used, since the values in the interval [9,1] are evenly distributed, while the values in the interval [1,1/9] are right biased. Along these lines different ideal standardisation proposals (Belton and Gear, 1983) and exponential scales (Lootsma, 1988), do exist but are not considered in this paper.

The method is as follows:

a) The first step is the decision maker's need to choose the most desirable option out of a set of possible, mostly-conflicting, alternatives which include strategies, investments, goods, etc.

b) The use of a set of criteria or characteristics for the alternatives defines their importance.

c) Once the criteria are defined and the alternatives known, the following step is to determine the level of importance of each of the criteria in selecting the alternatives. This level of importance is defined by calculating the relative weight of each criterion.

d) Having determined the weighting of the criteria, the different alternatives are weighted in relation to each criterion.

e) Two matrices are created from the above steps c) and d). One with column $nx1$ corresponding to the weighting of the criteria (where n is the number of criteria) and the other mxn composed of the weightings of the alternatives for each criterion (where m is the number of alternatives).

f) The product of the two matrices will result in a matrix with column mxl that shows the weightings of the alternatives in relation to all of the criteria together with their weight and importance.

Having explored the different stages in the method, they will be described later on in detail, particularly the procedure for obtaining the weightings and different matrices.

Assigning distinct importance to both the criteria and the alternatives may be carried out directly using a scale from 1 to 10 for each element. Initially, this seems to be simple but it is greatly complex for the human brain, especially the greater the number of elements to be compared.

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[1] Some applications exist in the area of non-market asset appraisal such as environmental assets (Cardells and Salvador, 2000) and intangible assets appraisal (Blasco *et al.,* 2002).

[2] The application of the method in groups requires a process of adding preferences entailing a certain complexity which has recently been resolved (Linares and Romero, 2002).

Table 1. Fundamental scale for paired comparison (Saaty, 1997)

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective.
3	Moderate importance	Experience and judgment slightly favour one activity over another.
5	Strong importance	Experience and judgement strongly favour one activity over another.
7	Very strong or demonstrated importance	One activity is favoured very strongly over another; its dominance demonstrated in practice
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	For compromise between the above values	Sometimes one needs to interpolate a compromise judgement numerically because there is no adequate word to describe it
Reciprocals of the above	If activity *i* has one of the above non-zero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*.	A comparison mandated by choosing the smaller element as the unit to estimate the larger one as a multiple of that unit

In order to overcome this problem, Saaty (1980) proposed carrying out paired comparisons between the different elements because the human brain is perfectly designed to make comparisons between two elements, hence proposing the scale in Table 1.

Using the scale in Table 1 the squared matrix A_{nxn} [1] is built using:

$$A = \left[a_{ij} \right] \quad 1 \le i, j \le n \qquad [1]$$

where a_{ij} represents the comparison between element *i* and element *j*.

This matrix must have the following properties (Saaty, 1986):

— Reciprocity:

If $a_{ij} = x$, then $a_{ji} = 1/x$, with $1/9 \le x \le 9$.

— Homogeneity: If the elements *i* and *j* are considered to be equally important then:

$a_{ij} = a_{ji} = 1$ and $a_{ii} = 1$ for all *i*.

— Consistency:

$a_{ik} * a_{kj} = a_{ij}$ is satisfied for all $1 \le i, j, k \le n$.

For the property to reciprocate, only *n(n-1)/2* comparisons are needed in order to build a matrix with a dimension of $n \times n$.

The last case or axiom of consistency occurs infrequently due to the innate subjectivity of the decision maker. This subjectivity seeks to objectify the procedure of the paired comparison matrix to the greatest extent possible since the main decision maker must compare the different elements several times in succession, as opposed to just once, in order to build the matrix. This will show any existing inconsistencies in the comparisons. The degree of inconsistency can be measured by calculating the Consistency Ratio (CR) of the matrix A[3] and if it does not exceed a certain percentage in relation to the rank of the matrix it is considered valid[4].

If the maximum consistency ratio is exceeded in a matrix, the weightings must be revised[5] or its consistency must be increased by goal programming (Gonzalez-Pachon and Romero, 2004).

In conjunction with the above, paired comparison matrices from the criteria and alternatives in relation to each of the criteria are built and

[3] An explanation of the Consistency Ratio is omitted here since it does not present any operative difficulty and would unnecessarily lengthen this paper. The reader may find more information about the Consistency Ratio in Saaty (1997).

[4] For matrices with rank 3, $CR < 5\%$; with rank 4, $CR < 8\%$; and with rank ≥ 5, $CR < 10\%$.

[5] One way of improving consistency when not considered satisfactory is to classify the activities using a simple order based on the weightings obtained when the problem was first dealt with, and develop a second paired comparison matrix, keeping in mind the prior categorisation. In general the consistency should be better.

in all cases their eigenvectors[6] are calculated (steps c and d).

The eigenvector for the criteria matrix will be identified as v_c and indicates the weight or relative importance of each of the criteria used in evaluating the set of alternatives under consideration.

The eigenvector of the alternatives matrix for a certain criterion will be identified as v_{ai} (column vector) and indicates the weight or relative importance of each of the alternatives for criterion i. The same number of eigenvectors v_{ai} ($v_{a1}, v_{a2}, \ldots, v_{an}$) are obtained given that there are criteria (n), with the number of elements of each eigenvector, equal to the number of alternatives (m). The set v_{ai} will make up the matrix of alternatives v_a.

Using step f) of the method, the matrix is multiplied by the alternatives by the criteria matrix [2]:

$$v_a \times v_c = w \qquad [2]$$

where $v_a = [v_{a1}, v_{a2}, \ldots, v_{an}]$, dim $(v_a) = m \times n$.

The result is a matrix w whose components express the relative weight of each alternative. This weighting allows the alternatives with greater or lesser interest to be classified and to quantify the level of interest for each alternative in relation to the others using all the available criteria and their importance.

The AHP was originally a multicriteria decision-making method finalising at this last step since its results allowed the best alternative to be found in relation to the criteria used. In the following point we shall see how to use this evaluation process while adding another step.

Adaptation of the AHP to farmland appraisal

The adaptation of the AHP to estimate the market value of a farm requires a prior adjustment of the multicriteria terminology to the technology of the appraisal methodology. In effect, while the nomenclature referring to AHP defines the criteria as elements, which are assigned weights, in the field of farmland appraisal the criteria will be substituted by the explanatory variables. On the other hand, the named alternatives in the AHP in farmland appraisal are the plots or farms themselves. These may have information and may be used for reference as well as the farm under appraisal.

Worthy of mention is that the regression matrix in the econometric model, formed by plots and explanatory variables, is equivalent to the one built in the AHP by criteria and alternatives. A comparison can be made between the final weighted matrix and the initial database matrix with a multiple regression model.

Conversely, as seen in the above section, applying the AHP to farmland appraisal obtains a column vector with the weighting of the different farms in relation to the explanatory variables and their weight. It is necessary to add another step in order to obtain the farm's value. This step consists in obtaining a value/weighting ratio from the values and weightings of the reference farms used.

The product of the ratio obtained from the weighting of the farm will be the value sought.

Application of farmland appraisal to a real case scenario

The following information corresponds to the market value of two farms. Farm 1 has a market value of 3,005 € ha^{-1} and farm 2 of 6,600 € ha^{-1}. We seek to estimate the value of a third farm[7]. The three farms are located in the same county and have comparable agronomic characteristics and farmland uses, as can be seen in Table 2.

Table 2 shows that the only observable differences which exist in the explanatory variables under consideration are productivity, soil quality and access.

[6] A sufficient approximation of the eigenvector can be obtained by opening the Excel spreadsheet program and using the MULT function in the function assistant. The calculation is carried out by multiplying the matrix by itself; the rows are added and the sums of each of their elements are averaged producing a column matrix. This column matrix is the approximate eigenvector of the initial matrix. The same operation is repeated (multiplying the resulting matrix by itself, obtaining the eigenvector) until the eigenvector obtained is the same to four decimal places which produces an approximate eigenvector.
Other ways of calculating the eigenvector exist such as the geometric mean of rows and other more elementary and imprecise methods. A computer program called EXPERT CHOICE can be used for AHP analysis, which returns the desired eigenvector, its consistency and a sensitivity analysis set and the like, upon defining the elements that are above the main diagonal (the values below the main diagonal are reciprocal).

[7] With the purpose of making this method easy to understand we use an example with just two controls. The same process can be carried out with more controls and a different amount of explanatory variables. When the elements of any of the levels (variable or control) exceed the number 7±2 (the magic number of Miller, 1956), the use of conglomerates is recommended (Escobar and Moreno, 1997).

Table 2. Characteristics of the farms

Farm	City	Crop	Value (€ ha^{-1})	Date of transaction	Area of farm (ha)	Type of irrigation	State of sanitation	Productivity	Soil quality	Access to the plot	Distance to Alzira (km)
1	Alzira (Valencia)	Orange var Navelina	3,005	December 2003	0.50	Trickle	Good	Normal	Good	Normal	0.60
2	Alzira (Valencia)	Orange var Navelina	6,600	February 2004	0.45	Trickle	Good	Good	Very good	Good	0.50
3	Alzira (Valencia)	Orange var Navelina	To be estimated	In course	0.50	Trickle	Good	Good	Good	Very good	0.55

The variables of surface area, type of irrigation and distance from cities are the same or similar for the three parcels. Thus, in the determination of the price, only the first three will be taken into account. Furthermore, these variables are usually important when fixing prices of agricultural property[8]. We shall call them x_1, x_2 and x_3. The focus of the AHP shown in section Methods is on forming appraisal criteria using the study of the relationships between the variables and the plots as shown in Figure 1.

The stated hypothesis that the market value depends of the variables of productivity, soil quality and access as formulated does not mean that the weight attached each of these variables will be the same.

In order to calculate these weightings, the expert[9] begins by creating the paired comparison matrix (Table 3) using the fundamental scale for paired comparison in Table 1.

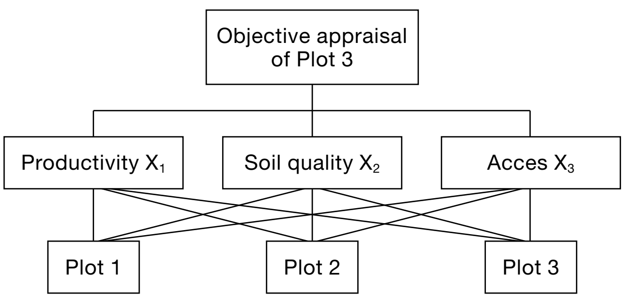

Figure 1. Graphic representation of the problem.

The explanation of the matrix in Table 3 is as follows: i) productivity is moderately strong in importance (4/1) compared to soil quality in determining the price of plots in this area; ii) productivity is strong in importance (5/1) compared to access in determining the price; iii) soil quality is the same or moderately more important (2/1) compared to access in determining the price.

The matrix is reciprocal, thus: i) the comparison of soil quality to productivity is 1/4, or 0.25; ii) the comparison of access to productivity is 1/5, or 0.20; iii) the comparison of access to soil quality is 1/2, or 0.5.

This matrix thus becomes the matrix shown in Table 4.

Once the matrix has been defined the consistency can be verified (CR = 2.37% < 5%), and the eigenvector can be calculated as previously shown.

The eigenvector obtained shows the weight of each of the explanatory variables with respect to the market

Table 3. Comparison matrix for explanatory variables

	Productivity	Soil quality	Access
Productivity	1/1	4/1	5/1
Soil quality	1/4	1/1	2/1
Access	1/5	1/2	1/1

[8] The productivity is the capacity that the plot has to produce income given its current agricultural condition, which is a fundamental product of good agricultural practices applied to it. The soil quality refers to the pedological characteristics of the soil. The accesses measure the ease of accessing the plot in order the carry out the different types of labour. The three variables used are qualitative, although productivity may be substituted for production, gross income or earning if they are known to the valuer. The difficulty of having this knowledge is that it justifies the use of AHP.

[9] One of the advantages of the method, as mentioned above, is that this process may be performed by one or more experts. In the latter case, an added solution must be found by applying goal programming (Linares and Romero, 2002). This possibility is of great interest since its use greatly reduces the subjectivity that, as already mentioned, is one of the weaknesses attributed to AHP.

Table 4. Paired comparison matrix for explanatory variables

	Productivity	Soil quality	Access	Eigenvector
Productivity	1	4	5	0.6833
Soil quality	0.25	1	2	0.1998
Access	0.20	0.50	1	0.1168

CR = 2.37%.

value of the farms which may, in turn, be converted to percentages: productivity, 68.33%; soil quality, 19.98%; access, 11.68%.

These results may be interpreted to mean that the productivity of the plots is weighted at 68.33% of their value, soil quality at 19.98% and access at 11.68%.

The following step comprises making a paired comparison of each of the plots (the two controls, 1 and 2 and the problem, 3) in terms of each of the explanatory variables, using the aforementioned paired comparison matrix and essential scale. Paired comparison matrix in terms of productivity is shown in Table 5. Paired comparison matrix in terms of soil quality is shown in Table 6. The paired comparison matrix in terms of the access variable is shown in Table 7.

Thus, the following are the results of the above process:

— A column matrix (Table 4, eigenvector column) created by the weightings or weights of the explanatory variables, which is denominated the explanatory variable matrix.

— Three column matrices (Tables 5, 6 and 7, eigenvector columns) with the weightings of the plots (the controls plus the problem) in terms of each explanatory variable. With these three column matrices a 3×3 square matrix is formed and known as the plot matrix.

Table 5. Matrix of the plots in terms of the productivity variables

	Plot 1	Plot 2	Plot 3	Eigenvector
Plot 1	1/1	1/3	1/7	0.1220
Plot 2	3/1	1/1	1/2	0.3196
Plot 3	4/1	2/1	1/1	0.5584

CR = 1.76%.

Table 6. Matrix of parcels in terms of the soil quality variable

	Plot 1	Plot 2	Plot 3	Eigenvector
Plot 1	1/1	1/2	1/1	0.2500
Plot 2	2/1	1/1	2/1	0.5000
Plot 3	1/1	1/2	1/1	0.2500

CR = 0.00%.

The product of the two above-defined matrices will produce a column matrix [3]:

$$\begin{pmatrix} 0.1220 & 0.2500 & 0.0974 \\ 0.3196 & 0.5000 & 0.3331 \\ 0.5584 & 0.2500 & 0.5695 \end{pmatrix} * \begin{pmatrix} 0.6833 \\ 0.1998 \\ 0.1168 \end{pmatrix} = \begin{pmatrix} 0.1446 \\ 0.3572 \\ 0.4980 \end{pmatrix} \quad [3]$$

The column matrix product defines the weighting of the plots (including the problem) in terms of all of the explanatory variables used and their weight; these were chosen because they were the ones that explain the price.

On the other hand, as the values of plots 1 and 2 are known, a ratio that compares the market value to the weighting can be obtained. Among the different formulas that exist for calculating the ratio, the barycentric ratio (Caballer, 1998)[10] was chosen. If applied in this instance the resulting ratio would be [4]:

$$R_B = \frac{\sum_{i=1}^{2} V_i}{\sum_{i=1}^{2} x_i} = \frac{3{,}005 + 6{,}600}{0.1446 + 0.3572} = 19{,}141.09 \quad [4]$$

Table 7. Matrix of plots in terms of the access variable

	Plot 1	Plot 2	Plot 3	Eigenvector
Plot 1	1/1	1/4	1/5	0.0974
Plot 2	4/1	1/1	1/2	0.3331
Plot 3	5/1	2/1	1/1	0.5695

CR = 2.37%.

[10] Given a set of market values V_i and explanatory variables x_i corresponding to farmland the ratio R_B can be defined as

$$R_B = \frac{\sum_{i}^{n} V_i}{\sum_{i}^{n} x_i}$$

This synthetic method is one of the best-known methods for obtaining ratios (another is the ratio method). The ratio method offers practically the same result (19,629.25).

The R_B ratio obtained expresses the value (€) per weighted unit. Multiplying the value of this ratio by the weighting of the corresponding plot gives the market value as shown below [5]:

$$V_3 = R_B * \text{Weighting Plot 3} = \\ = 19{,}141.09 * 0.4980 = 9{,}532 \text{ € ha}^{-1} \quad [5]$$

This result[11] implies a greater weighting of the appraised plot in comparison with plots 1 and 2 (0.49 as opposed to 0.35 and 0.14). Hence, it can be concluded that this plot is better than the control plots in terms of the explanatory variables used and consequently has a higher market value estimation.

Conclusions

A multicriteria methodology, namely the analytic hierarchy process (AHP), has been set out in this paper and has proven to be especially useful in the following instances: when data is only partially available; when using qualitative variables; or when using quantitative variables which are inaccessible to the professional and their quantification cannot therefore be deduced. This situation presents difficulties when applying conventional farmland appraisal methods.

The column vector, indicating the weightings of all the farm plots in terms of all of the explanatory variables and their corresponding weight, is obtained by means of the paired comparison matrices and their eigenvectors, not only for the explanatory variables but also for the farm plots (including the plot to be appraised) in terms of each explanatory variable.

Reference information regarding farm market values is used to calculate the ratio which compares the market value with its corresponding weight. This ratio in turn is used to ascertain the market value of the subject property.

Moreover, the application of AHP in farmland appraisal is an improvement over previous work dealing with multicriteria methods in which only quantitative variables had been used, whereas in this paper both quantitative and qualitative variables are used where only partial information is available.

Acknowledgements

The authors would like to thank the two anonymous evaluators of this paper for their opportune suggestions that have allowed us to sensibly improve both its content and clarity.

References

ALONSO R., LOZANO J., 1993. El método de las dos funciones de distribución: Una aplicación a la valoración de fincas agrícolas en las comarcas Centro y Tierra de Campos (Valladolid). Anales INIA. Ser Econ 9, 295-325.

AZNAR J., GUIJARRO F., 2005a. Métodos de valoración basados en la programación por metas: modelo de valoración restringido. Rev Esp Estud Agrosoc Pesq . In press.

AZNAR J., GUIJARRO F., 2005b. Modelo de valoración en ambiente de incertidumbre. Econ Agr Recurs Nat 4(1). In press.

BALLESTERO E., 1973. Nota sobre un nuevo método rápido de valoración. Rev Esp Estud Agrosoc Pesq 85, 75-78.

BALLESTERO E., CABALLER V., 1982. Il metodo delle due beta. Un procedimiento rapido nella stima dei beni fondiari. Genio Rurale 45-6, 33-36.

BALLESTERO E., ROMERO C., 1992. Il rischio d'errore nella stima secondo il metodo sintetico. Rivista del Catasto e dei Servici Tecnici Erariali (XLVII) 1, 5-12.

BELTON V., GEAR T., 1983. On a short-coming of Saaty´s method of analytic hierarchies. Omega 11, 227-230.

BLASCO A., RIBAL F.J., RODRÍGUEZ J.A., 2002.Valoración de intangibles en las sociedades anónimas deportivas en España. Jugadores y marcas. Proc. I Internacional Conference on Valuation and Appraisal. Valencia, July 3-5. pp.425-438.

CABALLER V., 1974. Los métodos sintéticos de valoración. Análisis y posibilidades. Rev Esp Estud Agrosoc Pesq 88, 105-121.

CABALLER V., 1976. El valor objetivo en los métodos estadísticos de valoración de inmovilizados. Rev Econ Polit 74, 57-75.

CABALLER V., 1998. Valoración agraria. Teoría y práctica. 4th ed. Mundi-Prensa, Madrid. 600 pp.

CABALLER V., AZNAR J., 2004. Metodología multicriterio aplicada a la valoración agraria. Rev Esp Estud Agrosoc Pesq 203, 35-47.

CALATRAVA J., CAÑERO R., 2000. Valoración de fincas olivareras de secano mediante métodos econométricos. Invest Agr: Prod Prot Veg 15(1-2), 91-104.

CAPLES S.C., HANNA M.E., PREMEAUX S.R., 1997. Least squares versus least absolute value in real state appraisals. The Appraisal Journal 65(1), 18-24.

[11] Using the ratio obtained with the ratio method (19,629.25) thus, V_3 = 9,775 € ha^{-1}

CARDELLS F., SALVADOR P., 2000. Manual de valoración de árboles y arbustos. Editorial UPV, Valencia, 298 pp.

ESCOBAR M. T., MORENO J. M., 1997. Problemas de gran tamaño en el proceso analítico jerárquico. Estud Econ Apli 8, 25-40.

GARCÍA J., GARCÍA L.B., 2003. Teoría general de la valoración. Método de las dos funciones de distribución. Ed. Fundación Unicaja, Málaga. 246 pp.

GARCÍA J., CRUZ S., ANDÚJAR A. S., 1999a. Il metodo delle due funzioni di distribuzione: Il modello triangolare. Una revisione**.** Genio rurale 11, 3-8.

GARCÍA J., TRINIDAD J.E., GÓMEZ J., 1999b. El método de las dos funciones de distribución: la versión trapezoidal. Rev Esp Estud Agrosoc Pesq 185, 57-80.

GONZÁLEZ-PACHÓN J., ROMERO C., 2004. A method for dealing with inconsistencies in pairwise comparisons. EJOR 158, 351-361.

HERRERÍAS PLEGUEZUELO R., GARCÍA J.,CRUZ S., HERRERÍAS VELASCO J.M., 2001. Il modelo probabilistico trapezoidale nel metodo delle due distribucion della teoria generale de valutazioni. Genio Rurale. Estimo e Territorio. Rivista de Scienze Ambientali (LXIV) 4, 3-9.

HERRERÍAS PLEGUEZUELO R., PALACIOS F., HERRERÍAS VELASCO J.M., 2002. Relaciones entre las familias de distribuciones Beta de varianza constante, mesocúrticas y de tipo Caballer. Proc. I Internacional Conference on Valuation and Appraisal. Valencia July 3-5. pp. 73-80.

ISAKSON H.R., 2001. Using multiple regression analysis in real estate appraisal. The Appraisal Journal (October), 424-430.

LINARES P., ROMERO C., 2002. Aggregation of preferences in an environmental economics context: a goal programming approach. Omega 30, 89-95.

LOOTSMA F.A., 1988. Numerical scaling of human judgment in pairwise-comparison methods for fuzzy multicriteria decision analysis. Mathematical models for decision support, NATO ASI series F, Computer and System Sciences, Springer-Verlag, Berlin. Vol. 48, pp. 57-88.

MILLER C.A., 1956. The magical number seven plus or minus two: Some limits on our capacity for processing information. Psychol Rev 63, 138-139

PALACIOS F., CALLEJÓN J., HERRERÍAS J. M., 2000. Fundamentos probabilísticos del método de valoración de las dos distribuciones. Proc. XIV Asepelt-Spain Meeting, Oviedo (published in CD-Rom).

ROMERO C., 1997. Una extensión del método de valoraciones de tierras de las dos distribuciones beta. Rev de Econ Polít 7, 47-62.

SAATY T., 1980. The analytic hierarchy process. Mc Graw Hill. NY.

SAATY T., 1986. Axiomatic foundation of the analytic hierarchy process. Manage Sci 32, 841-855.

SAATY T., 1997. Toma de decisiones para líderes. RWS Publications. Pittsburgh. 424 pp.

SEGURA B., GARCÍA R., VIDAL F., 1998. Modelos econométricos de valoración. Aplicación a la valoración fiscal. Invest Agr: Prod Prot 13(1,2), 221-224.