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GIS-based spatial decision support systemfor landscape planning
New system of analysis for decision making

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1 ABSTRACT

The risk of landscape impacts is subject of studies from different disciplines, but the integration of environmental and socio-economic factors has received relatively little attention. This paper discusses the main issues integrating a landscape analysis with an economic evaluation. The results are displayed in a GIS model. Additionally results and specific risk valuation problems are discussed in a detailed way.

This paper combines geographic and socio-economic data for social impact assessment. Socio-economic factors play an important role in the development of landscapes. The aim of this article is to assess the changing naturalness and biodiversity values under varying external human impacts.

Miscellaneous future scenarios of the main socio-economic factors and landscape changing models are considered and integrated. The methodology enables an assessment of the naturalness and biodiversity values of landscapes under changing socio-economic parameters.

A case study in a Spanish Nature 2000 site was developed. The visual landscape encompasses the aesthetics and the capacity of perception of the observer. In order to evaluate a landscape there are several methods and procedures discussed. A mixed method is proposed with direct valuation of representative subjectivity and a subsequent indirect analysis with an analysis of main components. This modified method attempts to solve the problem of subjectivity with groups of evaluators whose global opinion is representative, and is valuated using a survey that contains a list of adjectives with numeric values to facilitate its processing. A panel of experts will participate in the analysis of the main components. The technique of valuation of the landscape is the analysis of preferences that regards the value of a landscape as a function of the number of individuals who prefer it. The results of this assessment are integrated with the results of a contingent valuation over landscape at the time. The final result of this research is to gain the effective cost the population pressures over the landscape.

One of the main goals of this work is to evaluate effectively satellite information in connection to field sampling schemes. This will be archieved by linking interdisciplinary methods like spatial statistics, spatial landscape indexes, economic methods and geographical information.

To resolve the complex relations between the landscapes and socio-economic factors, the research work focuses on

- finding and describing operative indicators of sustainability
- suggesting future protective functions for cultural landscapes (e.g. agricultural and forest areas)
- determining the economy market value of natural resources and how could it be applied in the future.

2 INTRODUCTION AND PROBLEM DEFINITION

Sustainable development has become important in all aspects of political and scientific life. The European Union and other international organizations are trying to make sustainable development more effective through the use of indicators as measures of the environmental and sustainable development and by the incorporation of this measures into spatial planning. Nevertheless, although these tools provide data at municipal, regional or national scales wich are useful the political level, they are less useful for local use managers and decision makers because they lack a spatial component, below municipal level and are scale sensitive.

A key step in Spatial Regional Planning is the deliniation of land units that are similar relative to economics, social and environmental characterictis within a region.

The risk of landscape impact is subject of studies from different disciplines, but the integration of environmental and socio-economic factors has received relatively little attention. In this work the main issues integrating a landscape analysis with an economic evaluation is discussed. The results are displayed in a GIS model. Additionally results and specific risk valuation problems are discussed in detailed.

3 STUDY AREA

The agro- and natural ecosystems of the Special Protection Area (SPA) Encinares de los Ríos Alberche y Cofio –Fig. 1- (Holm-Oak woods of Alberche and Cofio Rivers) in Central Spain have an important role for wildlife conservation.

However, socio-economic changes in agricultural communities, urban development and uncontrolled recreational and tourist use of the landscape, have lead to altered disturbance regimes. As consequence of socioeconomic changes, land use changes, landscape configuration, patch structure and composition may change. A probable outcome of these changes is a loss of traditional activities and biodiversity.

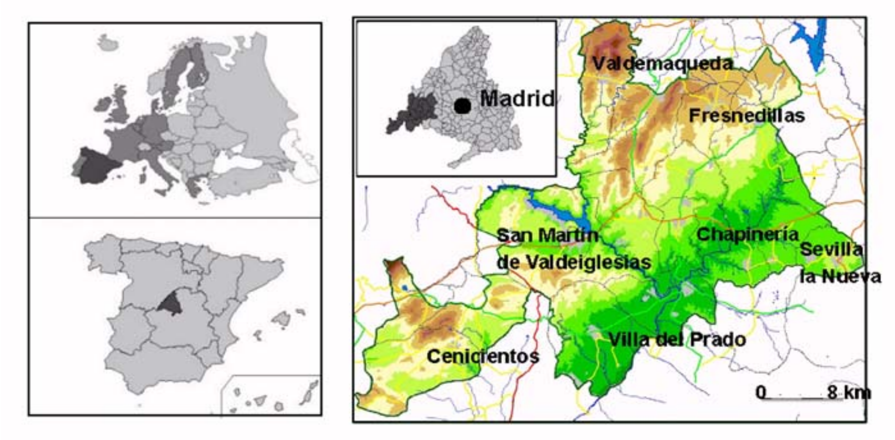


Figure1: Holm-Oak woods of Alberche and Cofio Rivers

4 GOALS

The main goal is the calculation of effective costs originated by the population pressures over landscapes, in other words, the willingness to pay for the conservation of the landscape relationated with the quality and fragility value. Evaluate effectively satellite information in connection to field sampling schemes. This will be achieved by linking interdisciplinary methods like spatial statistics, spatial landscape indexes, economic methods and geographical information.

5 METHODS

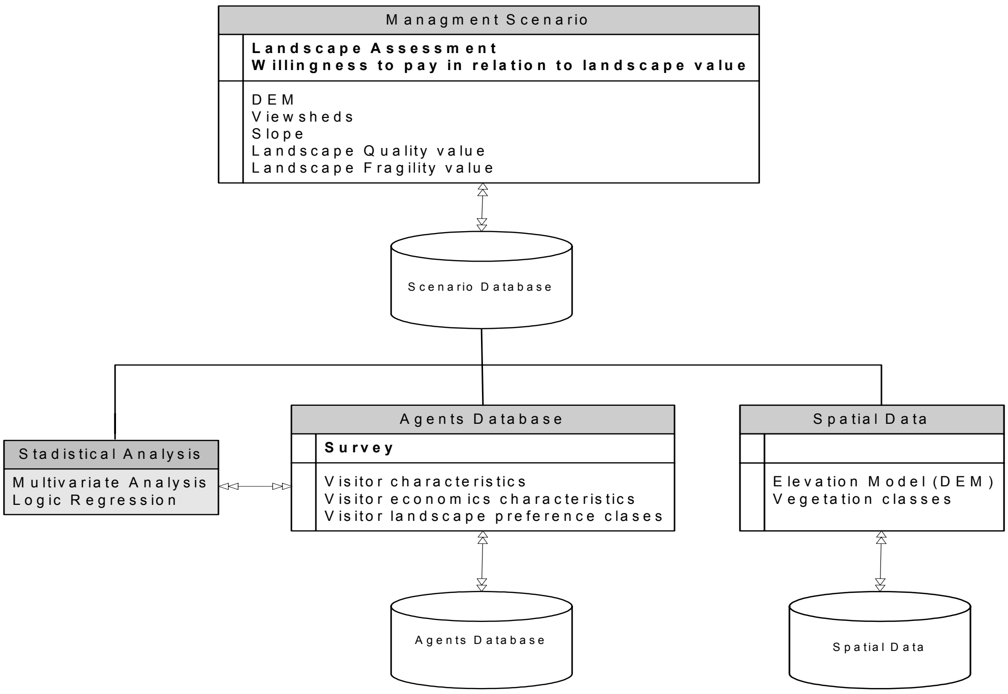
The method uses autonomus agents to simulate the willingness to pay for the conservation. Franklin and Graesser (1996) define an autonomus agent as follows:

"An autonomus agent is a system situated within and a part of an environment that senses the environments and acts on it, over time, in pursuit of its own agenda and so as to affect what it senses (an acts on in the future."

The agents are autonomus because once they are programmed they can move around their environment, ghatering information and using it to make decisions.

This is important because much of the economic value research is based on interviews or surveys, but this information fails to inform the manager/researcher how different management options might affect the overall experience of the user. By combining human agent and statistical analysis with geographic information systems, it is possible to study all these issues simultaneously and with relative simplicity.

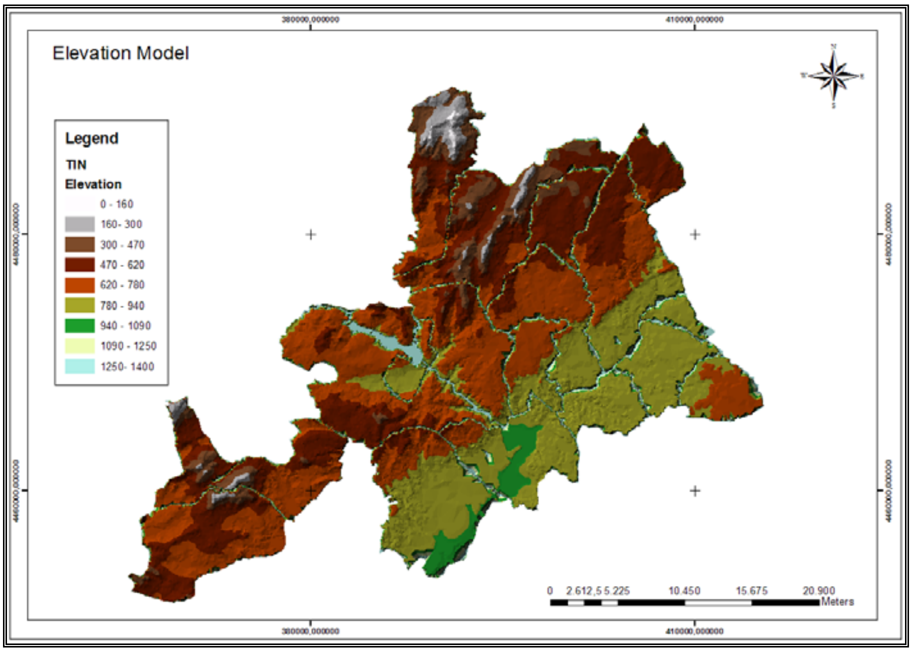
Figure 2 shows the relationships of the major componentes hierarchy of the spatial decision support system object. The spatial support system is comprised of the following components:



5.1 Spatial Data

Elevation Model (DEM)

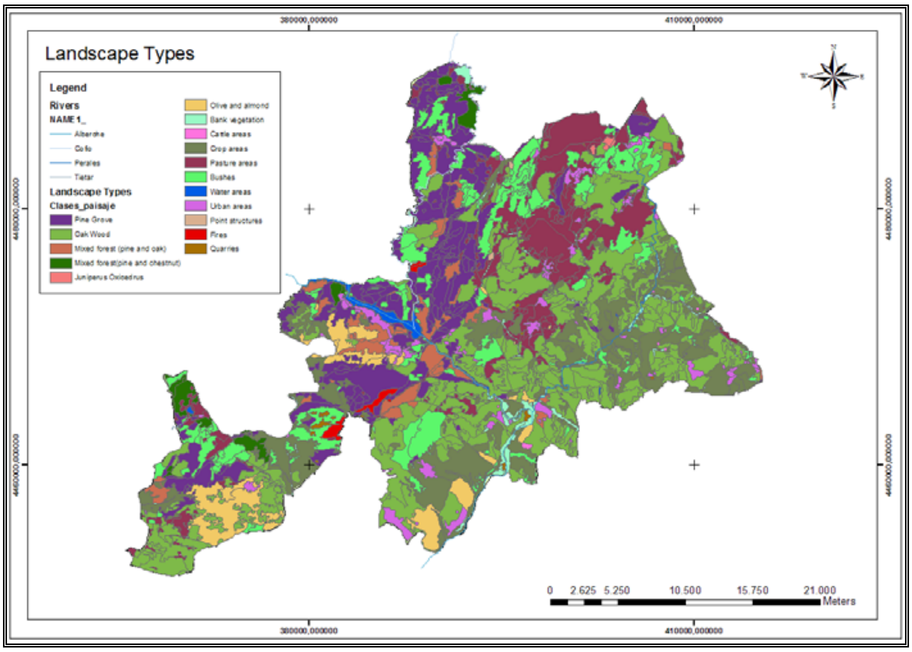
Elevation data is represented in a regular grid of elevations –Map 1-. They are used to assign elevations to the network and to calculate intervisibility between differents points.



Map 1: Elevation Model (DEM)

Landscape types

Landscape types are from a map of land uses. Lanscape types are defined by visiting the study area and with the map of land uses -Map 2-.



Map 2: Landscape Type

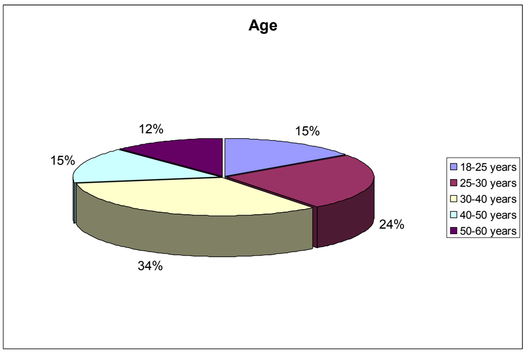
5.2 Agents Database

8.1.1 Survey

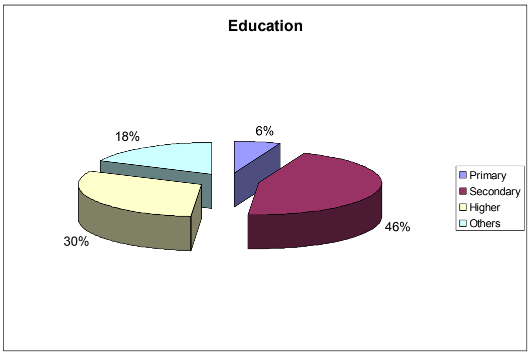
First, fotographs were taking in the study area from differents points wich were georeferenced with GPS in the study area. 500 fotographs were taking during sommer 2005 in the study area.Then, a questionary was designed and face-to-face interviews were conducted on individuals in the study area who were surveyed about their ladscape preferences and some personal socioeconomical aspects. The design of the questionnaires relate to actual and perceived causal relations among attributes and the level of the disggregation with wich attributes are specified. The purpose of these questionnaires is to explore the potencial for using stadistical preferences analysis to estimate the economic value of non.market environmental goods (Blamey, B y R.K., Rolfe, J.C. (1997)).

Visitor characteristics

56% of the surveyed are men and 44% are women. The most of the surveyed are ages between 30 and 40 years old –Graph 1- 46% of the surveyed finished their secondary education and 30% have finished higher education –Graph 2-.



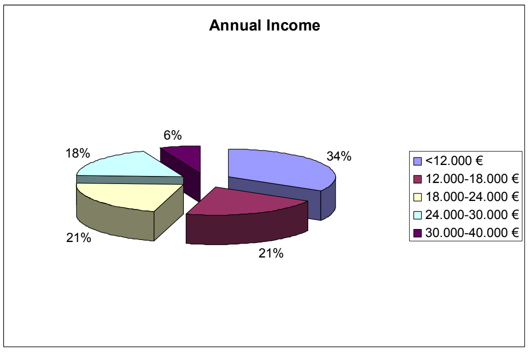
Graph 1: Age of the surveyed



Graph 2: Education

Visitor economics characteristics

34% of the surveyed have an annual income smaller than 12.000 €, 21% of the surveyed population have annual income between 18.000 € and 30.000 € - Graph 3-.



Graph 3: Annual Income

Visitor landscape preference classes

Preferences of the visitors related to the landscape are firstly for oak wood, juniperus oxicedrus areas, mixed forest (pine and oak), water areas and mixed forest (pine and chestnut). Negative preferences are for point structures as big aerial anntenas, urban areas, fire areas and quarries. In Table 1 the canonical discriminatory functions calculated with factor multivariate analysis are shown.

Landscape classes	Function	
	1	2
Crop areas	-,044	,214
Point structures	-1,205	,171
Urban areas	-,979	-,053
Pasture areas	,562	,099
Water areas	,392	-,276
Mixed forest(pine and chesnut)	,745	,050
Juniperus Oxicedrus	,807	,163
Mixed forest(pine and oak)	,773	,033
Bank vegetation	,764	,123
Pine grove	,502	-,130
Oak wood	1,066	,134
Fires/quarries	-,810	-,049

Table 1: Canonical discriminatory functions

5.3 Statistical Analysis

Statistical package (SPSS) has been used to analyse the landscape attributes. Multivariate analysis was used determining visual quality and visual fragility in relation with landscape classes. It is shown in the table 2.

Logic regression was used to determine the willingness to pay. The bid was included as explanatory variable of yes or no. The bid-rent approach was first developed by Alonso (1964). A comprehensive description of the bid-rent model and some of its extensions in a static framework can be found in Fujita (1989). Some of the attributes and the levels used in the analysis are showed in table 2

Attributes	**Levels**
Pine Grove	Visual quality Visual fragility
Oak Wood	Visual quality Visual fragility
Mixed Forest (pine and oak)	Visual quality Visual fragility
Bank Vegetation	Visual quality Visual fragility
Pasture areas	Visual quality Visual fragility
Water areas	Visual quality Visual fragility
Urban areas	Visual quality Visual fragility
Point structures	Visual quality Visual fragility
Fires	Visual quality Visual fragility
Quarries	Visual quality Visual fragility
Annual income	<12.000€ 12.000-18.000 € 18.000-24.000€ 24.000-30.000€ 30.000-40.000€ >40.000€
Annual willingness to pay	0€ <6€ 6-12€ 12-18e 18-24€ 24-30€
Additional Attributes	
Sex	Male Female
Age	18-25 26-30 31-40 41-50 51-60 >61
Studies level	Primary education Secondary education Higher education Others

Table 2: Levels and Attributes in the stadistical analysis

The results of the logic regression are showed in table 3; there are some attributes that stadistical result is very near to zero, so they have been eliminated of the regression model.

Variable/Attributes	Choice Model (B value)
Pine Grove (VQ)	3,65
Pine Grove (VF)	2,36
Oak Wood (VQ)	3,52
Oak Wood (VF)	2,41
Mixed Forest (pine and oak) (VQ)	3,3
Mixed Forest (pine and oak) (VF)	3,03
Mixed Forest (pine and chestnut) (VQ)	3,29
Mixed Forest (pine and chestnut) (VF)	2,43
Juniperus Oxicedrus (VQ)	3,39
Juniperus Oxicedrus (VF)	2,49
Bank Vegetation (VQ)	3,34
Bank Vegetation (VF)	2,47
Crop areas (VQ)	2,73
Crop areas (VF)	2,94
Pasture areas (VQ)	3,29
Pasture areas (VF)	2,5
Water areas (VQ)	2,92
Water areas (VF)	2,29
Urban areas (VQ)	2,712
Urban areas (VF)	2,27
Point structures (VQ)	2,26
Point structures (VF)	2,29
Fires/quarries (VQ)	2,37
Fires/quarries (VF)	2,73
[€willingness=1]	42,48
[€willingness=2]	42,48
[€willingness=4]	42,48
[€willingness=5]	42,48
[annual income=1]	-2,01
[annual income=2]	-2,05
[annual income=3]	-1,95
[annual income=4]	-2,02
Log-likelihood	2811,428
Log-likelihood Rest	2969,156
$\chi 2$	157,722
Rho^2	0,744

Value of t statistical aren't included because are all of them significant.

Table 3: Choice Model Coefficients

The model assuming that the probability of choosing the alternative y=1, the willingness negative to pay for the conservation is:

$$Log\ (P\ (y=1)/P(y=0)=Log\ (P_i/P_{(i-1)})=X^T{}_i\ B$$

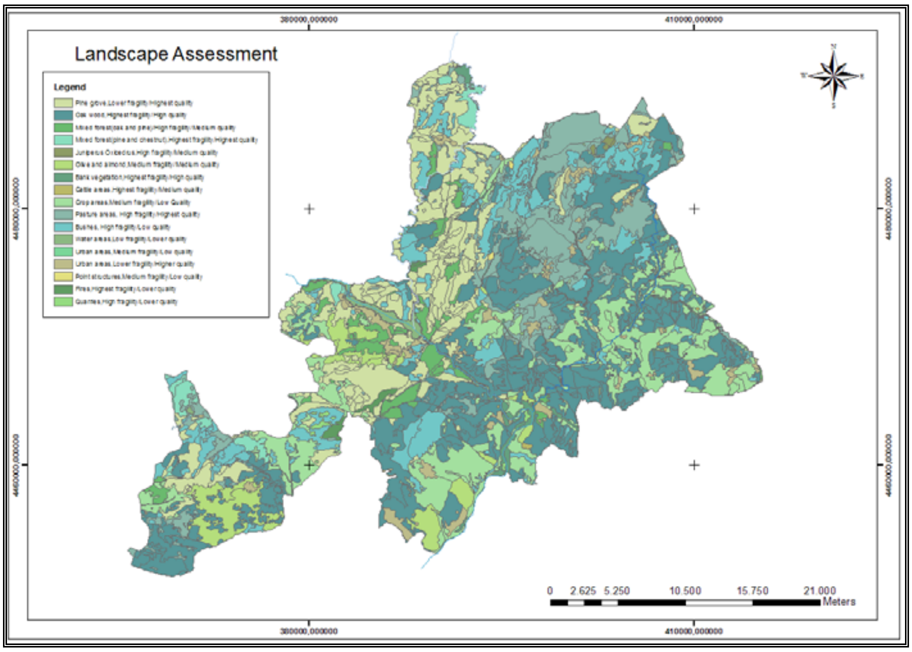
5.4 Managment Scenario

The management scenario is an aggregation of the DEM, a series of agents rules obtained in the statistical analysis and a set of runtime simulation conditions. Rules are assigned to each class of landscape defined related to the agents preferences and the willingness to pay.

The data are processed and the results are obtained wthin the management scenario.

5.4.1 Landscape assessment

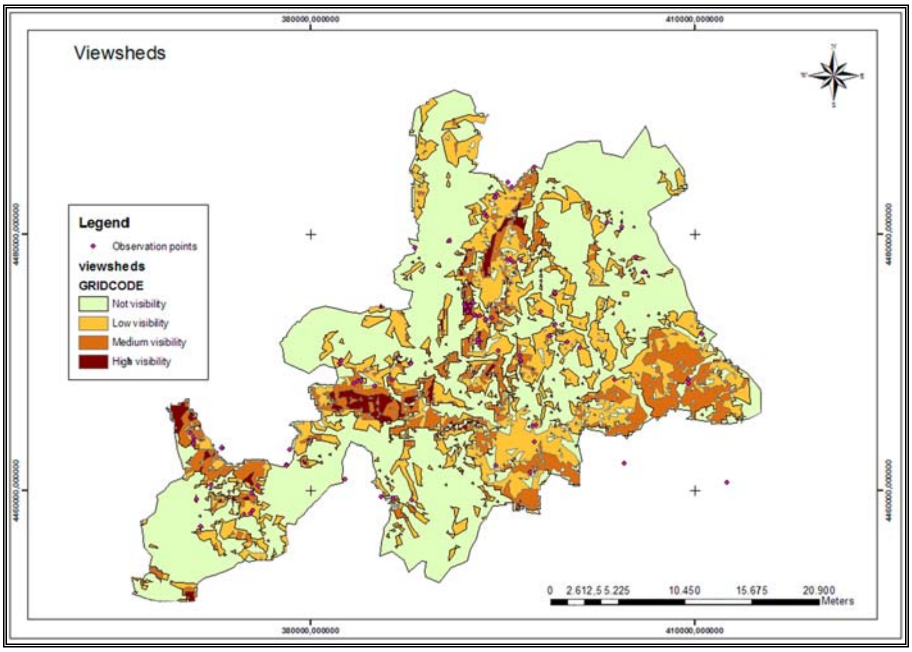
The Landscape assessment is the spatial integration between landscape classes, their quality and fragility value as shown in Map 3.



Map 3: Landscape assessment.

Viewsheds

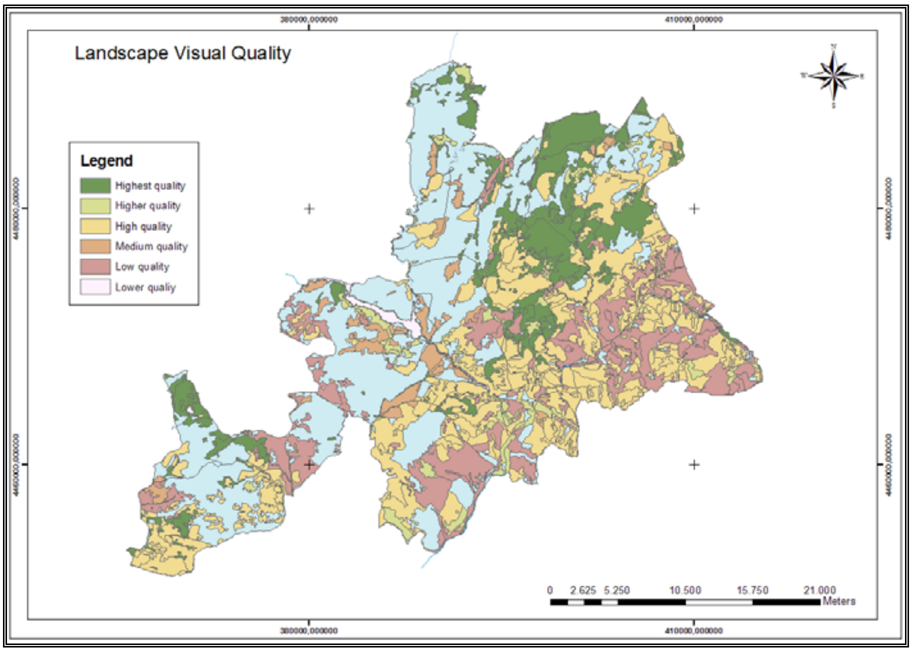
Viewsheds were calculated using the DEM from the points were the fotographs are taken. In Map 4 shows the different grades of visibility in the study area.



Map 4: Viewsheds

Landscape quality value

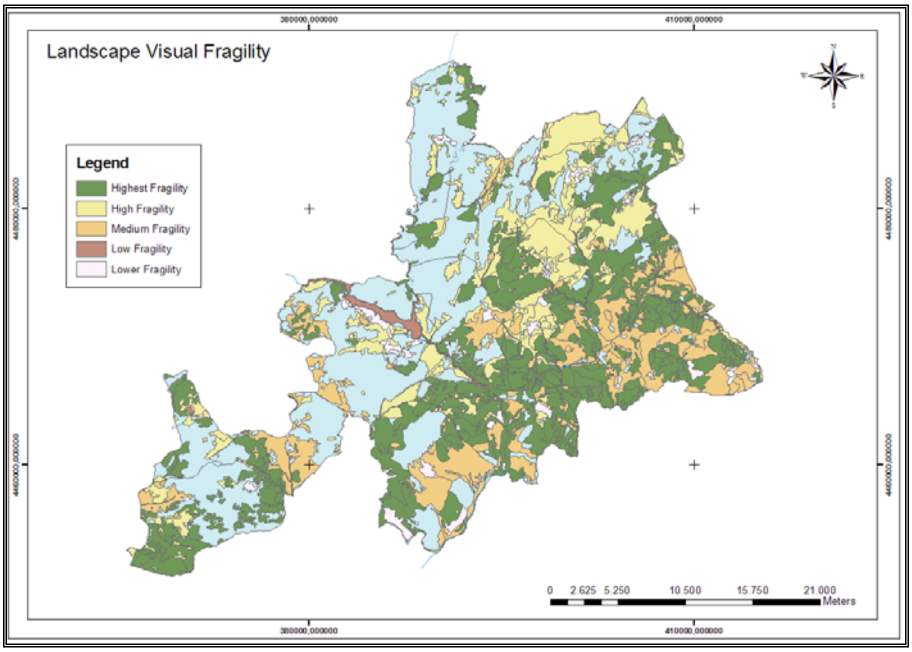
The Landscape quality value is calculated by using the DEM, viewsheds and preferences analysis. In Map 5 the different grades of the landscape visual quality in the study area are displayed.



Map 5: Landscape visual quality.

Landscape fragility value

The Landscape quality value is calculated by using the DEM, viewsheds and preferences analysis. In Map 6 the different grade of the landscape visual fragility in the study area are displayed.

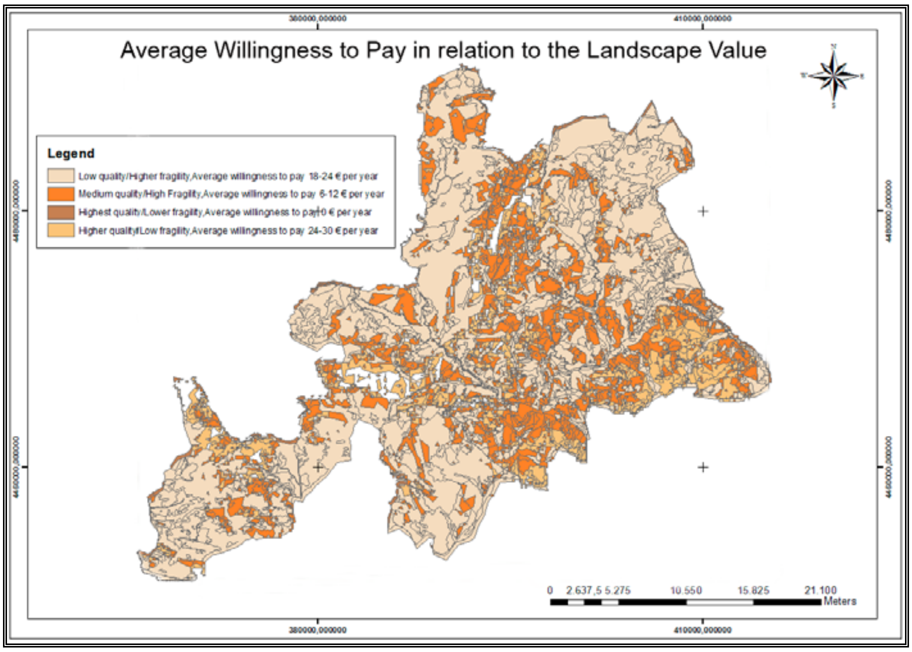


Map 6: Landscape visual fragility

5.4.2 Willingness to pay relationated with landscape value

Willingness to pay is calculated combining the landscape assesment, multivariate analysis and preferences analysis (logic regression). The willlingness to pay of the population is the higher (24-30 € per year) in areas with higher quality value and low fragility value. In contrast to this, in areas with medium quality value and higher fragility value, the population only has a willingness to pay 6-12 € per year. In Map 7 the different willingness to pay in the study area is shown.

It is interesting, that the areas, where the population would pay the highest quantity, are the smallest zones. The population is willing to pay in the most of the study area between 18-24 € per year in areas with low quality and higher fragility.



Map 7: Average willingness to pay relationated with landscape value.

6 CONCLUSIONS

Nowadays are required more intensive and innovative management techniques. Without a doubt, the development of these tools will significantly improve the ability of decision makers and users to use land units.

This decision making model is a general agent-based model for simulating the willingness to pay related with the landscape value for visitors and population in the study area.

This new decision model making model is designed as a management tool, manager can examine a broad range of management options, compare and contrast differents strategies.

The component architecture described in this paper allows us to build additional agents as a new components, change present components and integrate in the decision making model.

This paper is the considerable interest in integrating the behavioural decision modelling with traditional geographical information systems ecosystems models to provide the economy market value of the natural resources, moreover, develop temporal environmental economics models.

As discussed, the calculation of effective costs of the population pressures over the landscapes is very important for the management of natural protected areas.

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