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How Attractive Is Upland Olive Groves Landscape? Application of the Analytic Hierarchy Process and GIS in Southern Spain

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Abstract: The upland olive groves of Andalusia (Southern Spain) are an example of fragile landscape from an ecological point of view. The wildfire and soil erosion risks that can result in the desertification of the area are the main components of fragility. This paper focuses on the visual quality assessment of this agricultural system as a mean to their economic and environmental sustainability. The case study is represented by the upland olive groves of the municipality of Montoro where rural tourism is an important economic activity. We carried out a personal interview survey on 480 citizens to determine their visual preferences regarding three representative types of olive plantation landscape to be transferred to landscape level through a Geographical Information Systems (GIS). The Analytic Hierarchy Process (AHP) multicriteria decision-making technique was the method used to derive preferences from the survey. The results suggest that olive farming systems with grass vegetation cover between the trees are the preferred landscape type (0.42), followed very closely by the non-productive olive groves (0.41). The conventional olive farming system was the least preferred landscape (0.17). The visual quality map presents five categories, revealing that most of the olive groves in the study area belong to the very low visual quality category (93% of the total area).

Keywords: landscape visual quality; sustainable land use management, olive groves; Analytic Hierarchy Process (AHP); GIS; Spain

1. Introduction

This paper concerns the visual quality assessment of such a specific agricultural landscape as upland olive groves. This assessment is performed via the joint use of Geographical Information Systems (GIS) and the Analytic Hierarchy Process (AHP) decision-making technique.

Guzmán-Álvarez and Navarro-Cerrillo [1] identified around 200,000 hectares of Andalusian olive groves as marginal using topographical and edaphic criteria, most of them situated in upland areas. The marginal upland olive groves represent a fragile landscape from an ecological point of view. Their fragility consists of their vulnerability to wildfires and soil erosion that consequently lead to desertification of the area [2]. Abandoned non-productive olive groves have a high wildfire risk because of the dense growth of trees and spontaneous natural vegetation and the high oil content of unpicked fruits [3]. The presence of high soil erosion risk in upland olive groves is explained by the presence of steep and long slopes, the absence of any vegetation cover to protect the soil and the irregularity and intensity of rainfalls typical of this climate [4]. The desertification is a consequence of wildfire and soil erosion: once the soil has disappeared from the upland area, vegetation has difficulty rooting there and without vegetation the formation of new soil is seriously handicapped. Moreover, these upland landscapes play an important role in the provision of attractive cultural landscape, ecological diversity conservation, fixation of CO_2, etc. [5–8].

Upland olive groves comprise several agricultural systems, some of them of high importance since they represent an incentive for rural tourism and an essential element in the sustainable land use management.

Rural tourism in the study area is an important activity due to the fact that part of the Natural Park of Cardeña and Montoro is adjacent to it. The visitors of this Natural Park who come from the south must pass through the area of olive groves in order to reach their destination. Therefore, an improved visual quality of these olive groves would have a positive effect on the economic activity via rural tourism.

In the present study, we focus on the three most common types of olive plantation landscape in the study area (municipality of Montoro, Southern Spain, Figure 1):

- Non-productive olive groves (now being replaced by local wild plants and trees and therefore becoming Mediterranean forest);
- Integrated and organic olive farming systems with grass vegetation cover between the trees;
- Conventional olive farming system without grass vegetation cover between the trees.

Figure 1. Representative pictures of three most common types of olive landscape at the study area: (**a**) non-productive olive groves; (**b**) integrated and organic olive farming systems; and (**c**) conventional olive farming system.

The main objective of the study is to evaluate the visual quality of the study area and give recommendations for its improvement. In order to achieve this objective, a twofold methodology is developed: (i) evaluation of the visual perception of the three different types of olive groves using AHP decision making technique; and (ii) use of GIS technology to locate the most suitable olive groves to be restored.

2. Materials and Methods

2.1. Study Area

The upland olive groves in Southern Spain are mainly situated in Sierra Morena and Sierra Subbetica mountains. The study area of Montoro Municipality is a representative example of olive plantations consisting of agricultural systems and natural Mediterranean vegetation. This specific mixture of land uses is only typical of mountainous areas in Andalusia where olive trees are grown. The size of fragmented forest and olive plots could differ from place to place but landscape pattern is very similar and shares common environmental problems. The presence of the Natural Park of Sierra de Cardeña and Montoro adjacent to the study area gives more importance to the agricultural management of these olive groves, from a visual point of view.

The Municipality of Montoro is located in the province of Cordoba in Southern Spain (Figure 2). The territory enjoys a typical Mediterranean climate with irregular precipitation distribution during the year (less than 600 mm/year). It contains a variety of agricultural ecosystems (pasture, olive groves and annual crops) and natural forest/shrub vegetation near the agricultural areas. Its 58,103 hectares are divided into olive groves (34.2%), arable crops (8.1%), forest (17.5%), scrubland (28.7%), *dehesa* and other pastures (8.7%), water reservoirs (1.1%), urban area and infrastructure (0.8%) and other land uses (0.9%) [9].

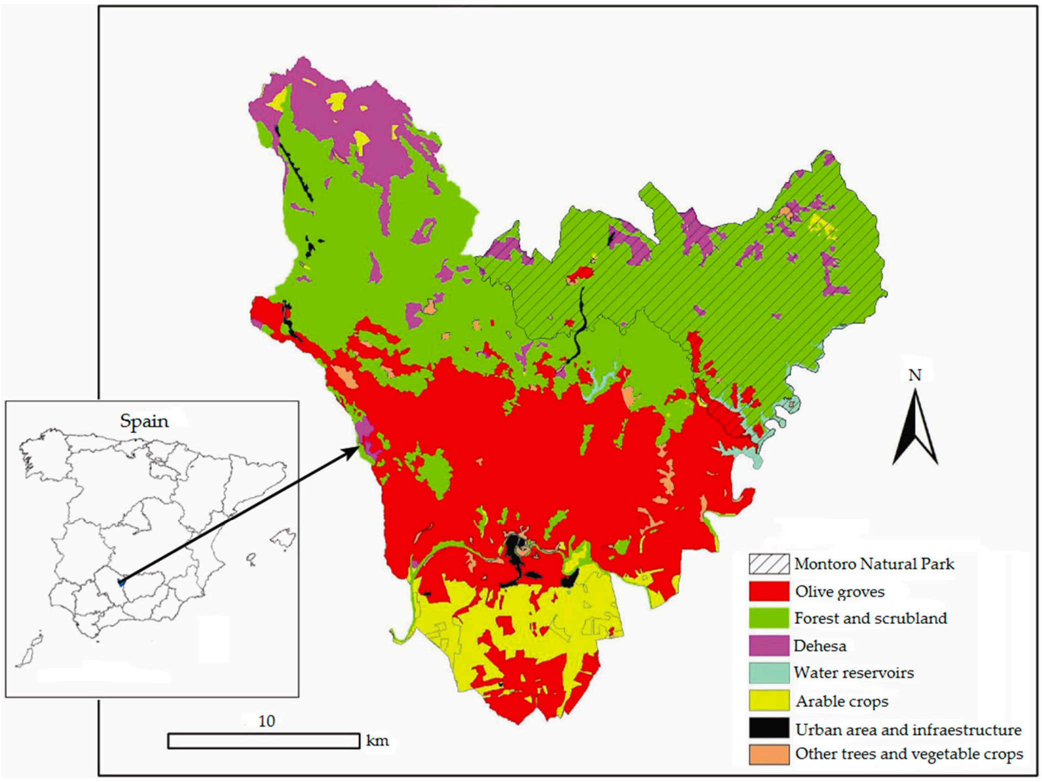

Figure 2. Study area map. Source: Own elaboration.

Most of the olive groves lack vegetal cover between the tree lanes, aggravating the soil erosion problem in steep areas and increasing the risk of desertification, which can consequently worsen the visual quality of the system.

This study area is particularly interesting due to its proximity to the Natural Park of Sierra de Cardeña and Montoro, home to some endangered species, the Iberian lynx being the most important, and as an example of the transition from intensive to extensive agricultural production systems.

2.2. Methodology

According to Lothian [10], the approaches to landscape visual quality assessment can be classified into two major groups: (a) Objectivist (physical) paradigm; and (b) Subjectivist (psychological) paradigm. The objectivist paradigm is based on the assumption that landscape visual quality is inherent to the landscape and subjectivity is presented as objectivity. In contrast, the subjectivist paradigm assumes that landscape visual quality is inherent to the perception of the viewer and objective evaluation of subjectivity [10]. In the present study, we developed a methodology that combines both of these paradigms and involves the following three phases:

- First phase: Analytic Hierarchy Process (AHP) opinion survey on public preferences regarding the three types of olive landscapes;
- Second phase: The visibility assessment of the study area;
- Third phase: The assessment of visual quality of the study area.

2.2.1. The Analytic Hierarchy Process (AHP) and the Opinion Survey on Public Preferences

A public opinion survey was conducted in the province of Cordoba following a quota sampling based on sex and age for each of the selected municipalities. Although this is a non-random sampling technique, it often produces very good results in opinion surveys [11]. First we selected at random three municipalities with less than 10,000 inhabitants, three with 10,000–25,000 inhabitants and one with more than 25,000. The probability of being chosen was proportional of the population size within the province. For each municipality, the number of interviews in each quota is proportional to the sex and the age distribution of the population. Finally, following random routes, the interviewees were selected, making this sampling technique similar to stratified sampling. With this procedure, we interviewed 243 women and 230 men with the following age distribution:

- Younger than 35 (251 interviewed);
- 36–50 (128 interviewed); and
- 50–69 (95 interviewed).

The quota of the persons older than 69 was not included due to the relative complexity of the questionnaire. Taking into account the size of the municipality, the sample is distributed as follows:

- Municipalities with less than 10,000 inhabitants (130 interviewed);
- Municipalities with 10,000–25,000 inhabitants (88 interviewed); and
- Municipalities with more than 25,000 inhabitants (255 interviewed).

In the seven municipalities, the survey was conducted through personal face to face interviews following a random selection of persons. Table 1 presents how we replicated real population in our survey, the chi-square tests for equality of distributions do not reject the null hypothesis of equality of sample and population proportions, supporting the representativeness of the sample.

Table 1. Comparison of sample quotas with the census data.

Variable	Groups	Census	Sample	Chi-Squared Test for Equal Frequencies
Size of the municipality	<10,000 10,000–25,000 >25,000	28.1% 23.7% 46.8%	27.5% 18.6% 53.9%	χ^2 = 2.187 *p*-value = 0.335
Sex	Male Female	46.8% 53.2%	48.6% 51.4%	χ^2 = 0.130 *p*-value= 0.718
Age	Less than 34 35–49 50–69	52.0% 25.9% 22.1%	53.1% 26.8% 20.1%	χ^2 = 0.236 *p*-value = 0.889

Source: Own elaboration based on Instituto de Estadística and Cartografía de Andalucía and survey data.

In addition to the pairwise comparison on visual preferences for the landscapes based on the photographs, socio-economic information (sex, age, place of residence, education level, type of job and income) was also gathered. A description is provided in the results session.

The AHP method does not make any recommendations on the quantity of judgments required for the evaluation exercise. Thus, this should be done according to the subjective opinion of the researchers involved in the project, taking into account time and financial possibilities.

The survey aims to evaluate the visual preferences for three different types of olive plantation landscape: conventional olive farming without vegetal cover, organic or integrated olive farming with grass vegetation cover between the trees, and non-productive olive groves. As in previous studies [12–18], we used photographs to represent the landscapes. The photograph-based visual quality assessment is a surrogate of the site visit survey. Studies realized by Shuttleworth, Daniel and

Vining, Stewart et al., Sevenant and Antrop [19–22] among others indicate that photograph-based preferences yield results similar to site visit preferences and provide an appropriate measure of landscape quality. For this purpose, we conducted several field trips to the study area where multiple photographs were taken (nearly 450 photographs). All field trips were conducted between February and May between 10:00 and 14:00, under clear sky conditions. Then, for each type of olive farming, and, based on expert judgment, ten photographs were selected (a total of 30 photographs, see Appendix A). The selection of these 30 representative photographs was done by experts with experience of surveying with photographic images and agreed upon by the researchers participating in the project. The main criterion of selection was the representativeness of the picture with respect to each of the olive plantation types considered. The unedited selected photographs were printed and used as hard copies during the survey.

In this study the Analytic Hierarchy Process (AHP) allowed us to derive weights of each landscape type presented by picture from the pairwise comparisons of these pictures. The AHP belongs to the family of multicriteria decision-making techniques developed in 1980 [23], and since then it has been applied in an important number of different applications [24] including for quality assessment of scenic forest management [25]. The AHP permits the quantitative evaluation of a discrete number of alternatives using a number of evaluation criteria. In the present study, we recall the AHP's ability to derive the priorities vector from the pairwise comparisons [26] and do not need to go to the alternative evaluation level.

If we assume that there are n criteria, and w represents the scores on the 1–9 scale, then the next Pair-Wise Comparison Matrix (or Saaty matrix) can be written:

$$\begin{pmatrix} w_1/w_1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_n \\ \dots & \dots & \dots & \dots \\ w_n/w_1 & w_n/w_2 & \dots & w_n/w_n \end{pmatrix} \times \begin{pmatrix} w_1 \\ w_2 \\ \dots \\ w_n \end{pmatrix} = \begin{pmatrix} nw_1 \\ nw_2 \\ \dots \\ nw_n \end{pmatrix}$$

The same formula in algebraic notation would be: $[A_{(i,j)}] \times [W_{(1,j)}] = [nW_{(1,j)}]$, where A is an $n \times n$ Pair-Wise Comparison Matrix that represents the ratio of ratings to weights, W is the vector of weights of the criteria, and n is the order of the matrix under consideration. The problem to solve is to find the vector of weights W from the A matrix. This kind of problem is quite common in physics and engineering and is known as the nonzero solution of the eigenvector/eigenvalue problem. In spite of the existence of more than one solution to this problem, Saaty [27] insist on the application of this method via a system of equations equal to one.

The answers collected via the typical AHP questionnaire (see Appendix B) are introduced in reciprocal matrices. Later, the mentioned principal eigenvector method is used to derive the priorities vector [27].

The above algorithm for the solution of the eigenvector problem is applied only in the case of total consistency of the Pair-Wise Comparison Matrix. In general, however, this condition is rarely met, so the eigenvector problem for the inconsistent case is written as: $[A] \times [W] = \lambda_{\max}[W]$, where $\lambda_{\max}$ is the maximum value of the eigenvector of matrix A, and W represents the corresponding weights of the right eigenvector. Normally, $\lambda_{\max}$ is rounded off to n ($\lambda_{\max} \geq n$). The closer the $\lambda_{\max}$ to n, the more consistent is the judgment recollected previously in the Saaty matrix. Thus, the difference $\lambda_{\max} - n$ could be used as an indicator of the degree of inconsistency (this difference should be zero for a completely consistent matrix). Nevertheless, an alternative kind of measurement known as the Consistency Index (CI) has been proposed [27]. If we define $a_{ij} = (w_i/w_j)d_{ij}$, then:

$$\mathrm{CI} = (\lambda_{\max} - n)/(n-1) = -1 + \frac{1}{n(n-1)} \sum_{1 \leq i < j \leq n} \left[d_{ij} + \frac{1}{d_{ij}} \right] \quad (1)$$

where CI is interpreted as the average inconsistency accumulated in the matrix. In the next step [23], proposes comparing the Consistency Index with the Random Index (RI). This RI is calculated like a CI (Equation 1), but for randomly composed reciprocal matrices with an order from 1 to 15. On the basis of these two indices, the Consistency Ratio (CR) is calculated as CR = CI/RI and, according to Saaty, [23,27,28], it should be lower than 0.1. This means that the inconsistency of the responses should not exceed 10%. An inconsistency between 0% and 10% can be regarded as normal. In cases where the CR is higher than 10% the responses should be revised in detail and the evaluation questions must be repeated until the CR < 0.1.In this study the MATLAB platform is used with the free extension of Scott [29] for mathematical computation of eigenvector and Consistency Ratio.

Initially the AHP was proposed as a single decision-making technique. However, after several successful applications this technique was extended to include the group decision-making cases. The most commonly used procedures to proceed with group decision-making in AHP are: Aggregating Individual Judgments (AIJ) and Aggregating Individual Priorities (AIP) [30]. In the present study the AIJ procedure is used. Forman and Peniwati [30] suggest the use of the geometric mean as a Pareto Principle satisfied in the case of AIJ procedures.

In considering the practical implications for this study, in the survey each respondent evaluates all possible combinations of a set of three photographs (one for each type of olive plantation landscape), undertaking $3 \times (3 - 1)/2 = 3$ pairwise comparisons [23]. In order to avoid a "picture effect", the representative picture in each set was selected at random from the ten available for each olive tree landscape. During the face to face interview, the set of three pictures were labeled as "A", "B" and "C". Thus, the person was asked to choose one photograph of each pair (AB, AC, and BC) and indicate the degree of preference in 1–9 ordinal scale: 1 = equal value given to both landscapes, 3 = weak preference of one landscape, 5 = notable preference of one landscape, 7 = strong preference and 9 = absolute preference of one of the two landscapes. In some cases, the intermediate values 2, 4, 6 and 8 were used. The evaluation of landscape via pairwise comparison of representative pictures has previously been done in other studies [31–33] using the Alho et al. [34] regression method.

2.2.2. Visibility Assessment of the Study Area

The visibility assessment is an important part of the general exercise of landscape visual quality assessment [35]. The potentially visible areas should receive more attention (and therefore value) than those that are not potentially visible [36,37].

The procedure of visibility assessment is performed through a Geographical Information System (GIS) using QGIS (Geographic Information System. Open Source Geospatial Foundation Project) based on the Digital Elevation Model (DEM) [38,39]. The potential observation points were derived from four potential observation areas: urban settlements, motorway, local roads and paths. For the urban settlements we chose 72 points within urban areas. Some of the points were selected during the field trip to the town of Montoro, others were added at random. For the high speed motorway, we chose 27 points homogenously distributed along the motorway within the area of Montoro municipality. For the local roads, we chose 192 points homogenously distributed along the network. The local paths were represented by 202 points that were also homogenously distributed. The quantity of observation points was subjectively established by the researcher-participants of the project following the criteria of area coverage (for high speed motorway, local roads and paths) or importance (for urban settlements).

The viewsheds were calculated separately for each of the selected areas of observation (urban settlements, high speed motorway, local roads and paths). The four resulting raster layers were joined to obtain a global visibility map for the olive groves of Montoro on the basis of selected observation points.

The input data were: a land use map (1999; 1:50,000) corresponding to the study area [9]; aerial monochrome orthophotos (2001–2002; 1:5000); and color orthophotos (2005; 1:10,000) in order to check the accuracy of the land use map; road infrastructure and secondary paths maps (1999; 1:25,000); DEM in raster format corresponding to the study area (10 m $\times$ 10 m raster cell size). The DEM was assumed to be a reasonable approximation of the digital surface model due to the absence of tall forest trees (natural Mediterranean vegetation usually takes the form of bushes or "matorral" and Mediterranean oat plants and does not exceed the height of olive trees) and the scarcity of rural buildings that might interfere with the views from the potential observation points. All geographical materials are represented in European Datum 1950, Zone 30N (Spain and Portugal).

2.2.3. Assessment of Visual Quality of the Study Area

The visual quality assessment is provided in the vector format (the visibility raster map is converted to vector format). The outcome of the opinion survey on public preferences regarding the three types of olive plantation landscape is introduced into GIS (the weight is assigned to each olive farming type in the land use layer). The final visual quality assessment is performed in QGIS (Geographic Information System. Open Source Geospatial Foundation Project) where two layers are overlapped. As an outcome of this operation, the crossed attribute table (with the fields containing the attributes of two input layers) and map are obtained. The attribute table is related to the visualized map. On the basis of the table, it becomes possible to categorize the olive plantation area according to visibility and visual preferences. In the new field created in the attribute table five categories of visual quality are defined: very low; low; medium; high; and very high. The detailed description of each category is presented in the results section.

3. Results

3.1. AHP Opinion Survey

A total of 480 citizens were interviewed using a typical AHP questionnaire, and 473 were considered valid. Half of the 473 interviewed lived in rural areas. As far as education is concerned, 26 of those interviewed had no basic education, 114 attended school, 150 higher education, and 182 university or higher level. With respect to occupation, 33 were agricultural workers, 91 students, 40 self-employed off-farm, 201 workers outside the agricultural sector, 22 unemployed, 45 retired, 25 housekeepers and 14 other occupations. The household income distribution was 30 with less than 600 Euro per month, 183 between 600 and 1500, 159 between 1500 and 3000, 34 between 3000 and 5000 and 21 earning more than 5000 Euro.

The photographs used in the survey are shown in the Appendix A. After the application of the AIJ procedure, we reached the following weights (Table 2).

Table 2. Relative weights of the three types of olive plantation landscape obtained from the survey.

Title 1 Olive Landscapes	Conventional Olive Farming System	Olive Farming System with Grass Vegetation Cover between the Trees (GVC)	Non-Productive Olive Groves
Relative weights CR = 0.0005; CI = 0.0003	0.1772	0.4155	0.4073

Source: own elaboration.

According to these results, the olive groves with grass vegetation cover between the trees are the most preferred landscape from the visual point of view (weight of 0.42). The non-productive olive groves are valued at almost the same level (weight of 0.41) (Table 2). The olive groves with a conventional farming system are clearly identified as the least preferred landscape type. These weights were transferred to the corresponding GIS layer (Figure 3).

As Figure 3 shows, most of Montoro's olive groves are conventional farming systems (almost 96% of the area).

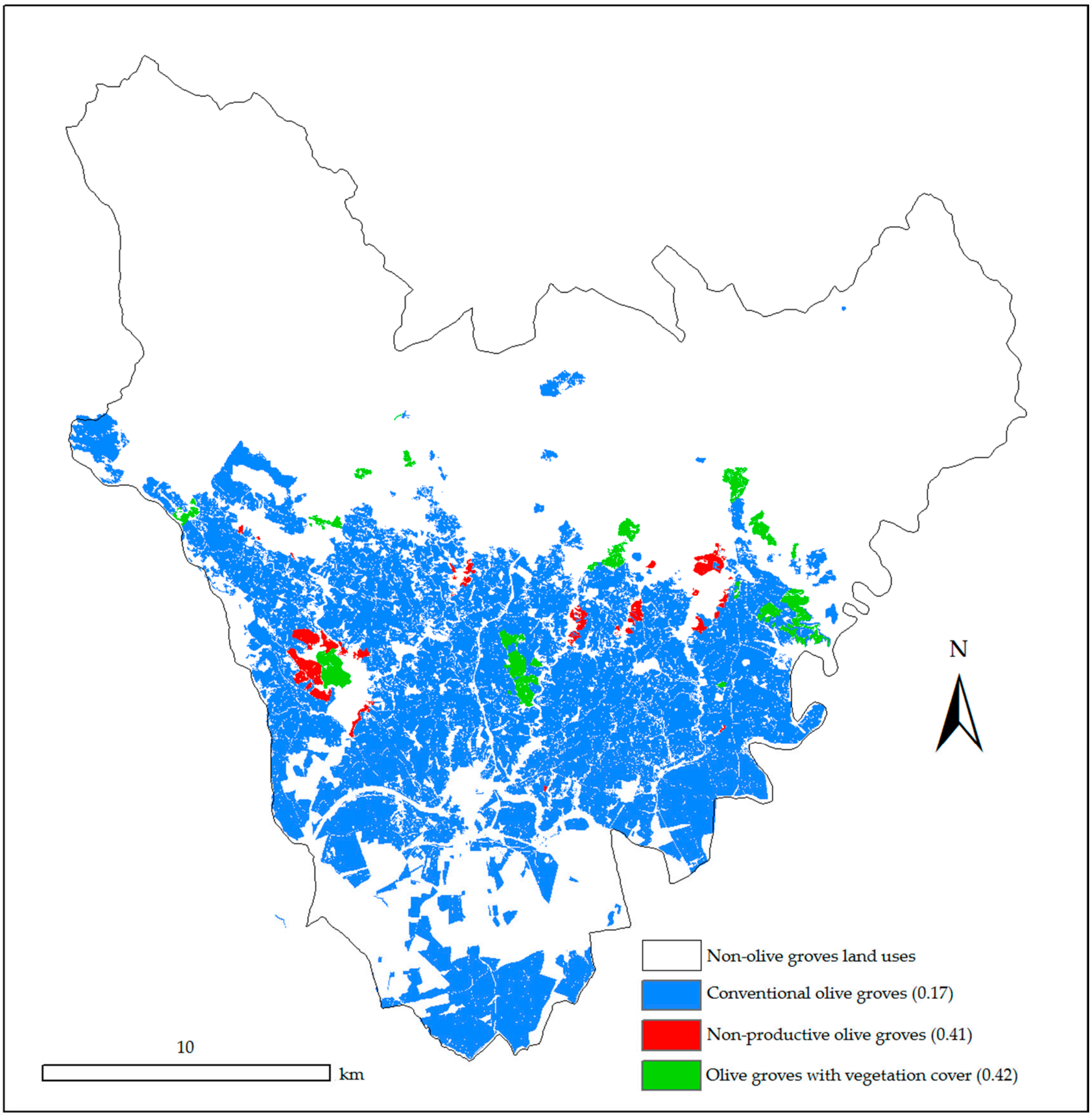

Figure 3. Map with the geographical situation of three types of olive groves.

3.2. Visibility Assessment

We assessed the visibility of all olive plantation landscapes considered in the study from several possible points of observation (urban area of Montoro, a motorway, roads and paths). The resulting map is presented in Figure 4. The pixel values vary between 0 and 57 indicating how many times each spot of the olive plantation could be seen from the possible observation points.

As this output map shows, the most visible areas are situated near the Montoro urban zone, and close to the main roads.

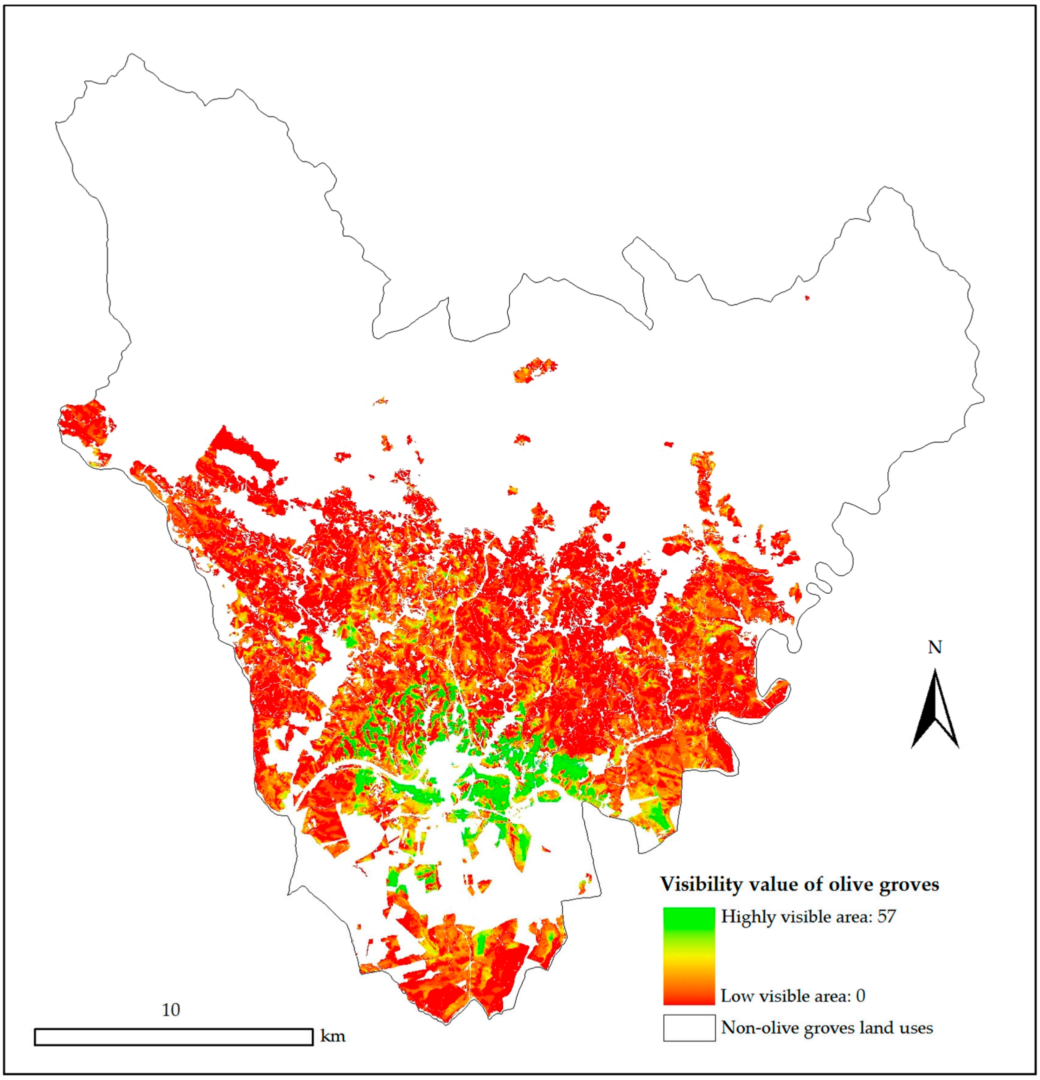

Figure 4. Visibility map of the study area.

3.3. Visual Quality Assessment

Figure 5 shows the results of the visual quality assessment of the olive groves of Montoro.

As we explained in the Methodology Section, five categories of visual quality were defined as follows:

(1) Very low visual quality: Conventional olive groves with (0–10] visibility values and non-productive areas and olive groves with vegetation cover with 0 visibility values. Occupies 16,531.4 hectares (93%).

(2) Low visual quality: Conventional olive groves with (10–57] visibility values and non-productive areas and olive groves with vegetation cover situated at spots with a visibility value of 1. Occupies 952.9 hectares (5%).

(3) Medium visual quality: Non-productive olive groves and olive groves with vegetation cover situated at spots with a visibility value within the interval [2–6). Occupies 190.9 hectares (1%).

(4) High visual quality: Non-productive olive groves and olive groves with vegetation cover situated at spots with a visibility value within [6–10). Occupies 27.8 hectares (0.2%).

(5) Very high visual quality: Non-productive areas and olive groves with vegetation cover situated at spots with a visibility value within [10–57]. Occupies 3.2 hectares (0.02%).

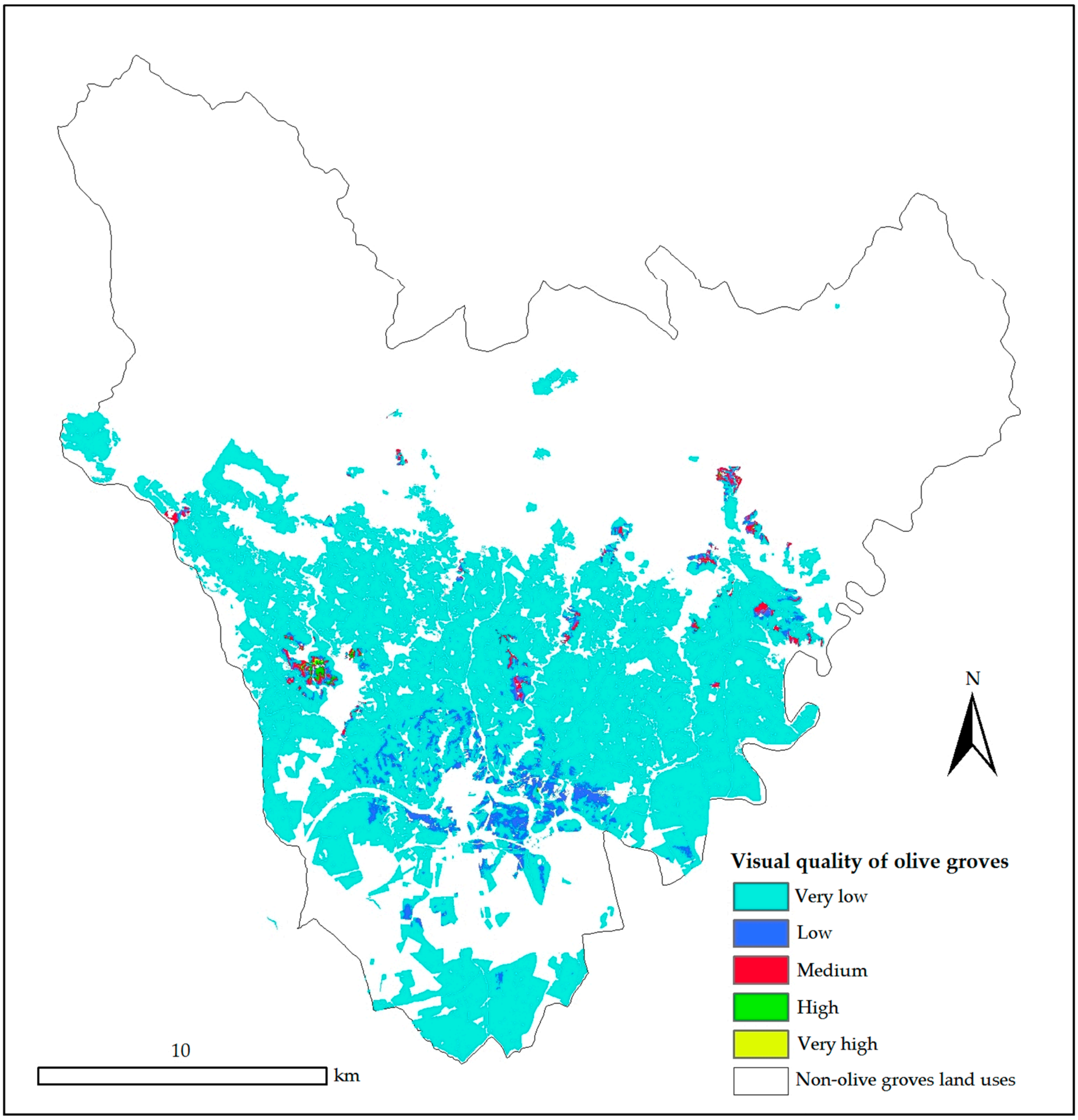

Figure 5. Visual quality assessment of Montoro.

As shown in Figure 5, most of the olive groves are categorized as very low visual quality (93% of the total olive groves). This fact points out on how to increase rural tourism in the area. If visitors could enjoy a more attractive landscape the number of visits and overnight stays will increase, bringing more employment opportunities and investment to the municipality. The visual improvement of olive groves can be done through a specific land use policy that encourage owners to implement specific measures like using vegetation cover between the trees or transforming less productive olive groves into Mediterranean forest. These actions would make the local Montoro´s landscape more attractive for locals and visitors.

4. Discussion

The model proposed in this study evaluates the visual quality of the upland olive groves of Montoro at landscape level. The evaluation of visual quality is always a challenging process due to its "fuzzy" and subjective nature [40,41]. Therefore, we aimed to convert the subjective perception of the population into numerical data that allow us to quantify the visual quality of an agricultural system.

In order to achieve this objective, we combined a multicriteria technique, the Analytic Hierarchy Process (AHP), with GIS technology. Both (AHP and GIS) prove themselves to be efficient and sufficient for this kind of assessment, as other studies indicate (for example, Vizzari [42]).

Several methodological approaches have been proposed to handle the assessment of the landscape visual quality. One approach evaluates the elements that compose the landscape scene and obtain the overall value by aggregation of the parts [43,44]. A second approach evaluates the landscape visual quality as a whole [15,45,46]. Alternatively, a combination of both approaches can be used [16,17,47]. The methodology proposed in this study belongs to the second group.

An important issue is the limitation of the evaluation exercise to three landscape types. In theory the AHP would allow the evaluation of up to nine photographs at the same hierarchy level [48], but for nine photographs the number of pairwise comparisons would increase to thirty-six, making it difficult for a person to evaluate such a number in an outdoor survey. This can be overcome using the hierarchy structure of the AHP, but the possibilities for increasing the number of photographs under consideration are still limited. Another alternative proposed by Blasco et al. [49] is to use the typical AHP pairwise comparisons combined with regression analysis, resulting in a lower number of comparisons [34].

It would also have been possible to gather information about the importance of separate elements of the olive groves (vegetation cover, tree shape, color of the soil, etc.), as conducted by Liao, and Nogami [50] for forest scenes with artificial stands. However, the main objective of the present study is to combine visual quality with geographical visibility rather than to explore how overall visual quality is formed.

The seasonal effect of the photographs should be considered as well. All the selected pictures presented in the survey correspond to the most attractive season (spring). Nevertheless, the landscapes vary considerably depending on the season. In summer, the driest time, the olive groves, with and without the grass cover, could be less visually attractive than non-productive olive groves. In Switzerland, the question of landscape visual quality dependence on seasonality was addressed by Schüpbach et al. [51]. However in a dry climate, like that of Southern Spain, this issue needs further research since the recreational demand of the agricultural systems decline.

The conclusion that non-productive olive groves and olive groves with vegetation cover are more valued from a visual point of view should be limited to upland zones where a high level of landscape fragmentation exists. Therefore, visual quality could be related to landscape contrast. Consequently, the improvement of the visual quality of other olive groves, like the lowland olive groves, could benefit from other types of measures in addition to the use of grass cover.

The selection procedure of possible observation points in the visibility analysis relies on the researchers' judgment. The information gathered during the field trips to the study area allows us to support this selection. In case of limited information regarding the study area an alternative procedure could be the use of a grid net. However, this is not the case of the present study where the data availability was sufficient to determine the observation points. Other authors [52] advocate the use of a methodology based on building a triangle network from DEM in a regular square grid, which yields higher precision in a viewshed assessment than the traditional methods.

Finally, it is worth highlighting the importance of the public opinion in this type of analysis. Certainly, the same survey in a different cultural environment would yield very different results [53], even for the same agricultural system.

5. Conclusions

In the present study we apply the AHP multicriteria technique to assess the perception of visual quality of three types of olive groves: conventional production without grass cover between the trees, organic and integrated production with grass cover between the trees, and non-productive olive groves. The study reveals that the last two types are the preferred landscape scenes with weights of 0.42 and 0.41 over 1, respectively.

The visual quality of each type of olive plantation is combined with geographical information in order to take into account the visibility of the plantation. The resulting map allows us to determine the visual quality of olive groves landscape, divided into five classes: (1) Very low visual quality (occupies 16,531.4 hectares or 93% of the total area); (2) Low visual quality (occupies 952.9 hectares or 5% of the total area); (3) Average visual quality (occupies 190.9 hectares or 1% of the total area); (4) High visual quality (Occupies 27.8 hectares or 0.2% of the total area); and (5) Very high visual quality (occupies 3.2 hectares or 0.02% of the total area).

According to these results, a huge change in local land use policy is needed in order to improve visual attractiveness of the area and make land use management more sustainable.

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Author Contributions: Olexandr Nekhay had the original idea for the study, conceived and designed the experiments and analyzed the AHP and GIS data. Manuel Arriaza took the photographs and designed the population survey. All authors drafted the manuscript, and approved the final one.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Figure A1. *Cont.*

Conventional olive farming system

Olive farming system with grass vegetation cover between the trees

Non-productive olive groves

Figure A1. Pictures of Three Types of Upland Olive Groves Shown during Personal Interviews.

Appendix B Pair Comparisons of Three Different Pictures According AHP Method

Pairwise comparisons (from 1 = both pictures have the same visual quality to 9 = absolute preference of one picture over other).

D1	A. Picture of non-productive olive groves
	B. Picture of olive farming system with grass vegetation cover between the trees

	1		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**

D2	A. Picture of non-productive olive groves
	C. Picture of conventional olive farming system

	1		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**

D3	B. Picture of olive farming system with grass vegetation cover between the trees
	C. Picture of conventional olive farming system

	1		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**

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