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INTEGRATING SOCIAL PREFERENCES AND EXPERTS' SUBJETIVE INFORMATION INTO AGRICULTURAL LAND USE OPTIMIZATION

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The production system management of olive plantations (*Olea europaea* L.) in Southern Spain is analysed from an economic, social and environmental perspective. The economic approach addresses the viability of the farming activities, the social criterion aims to prevent population loss in rural areas, whereas the environmental analysis involves the consideration of the reduction of soil erosion, the improvement of ecological diversity, the control of fire risk and the provision of quality agricultural landscapes.

The main purpose of the present work is social optimization of the olive farming area in the Montoro municipal territory (Andalusia, Spain). This optimization could serve for the local administration as a support guide to allocation of subsidies and corrective measures. To achieve this purpose the following exercises was carried out: *i*) six main functions performed by olive farming were selected; *ii*) the selected functions was evaluated by the local population via the AHP questionnaire (480 respondents); *iii*) at the same time several territorial models were made that evaluate the performance of the area with respect to each function under consideration; *iv*) the expert opinions about the performance of each alternative with respect to the selected function were collected; *v*) finally each of four considered alternatives and its most suitable allocation were evaluated.

According to the population's responses, the groups of environmental and socio-economic functions have equal importance (42% each), leaving the provision of agricultural landscape with a weight of 15%. Individually, keeping the rural population in the villages (24%), the production of olive oil (18%), the prevention of wildfires (17%) and the reduction of soil erosion (16%) are the most valued functions.

In order to aggregate public and expert opinions we have used the AHP technique which makes pair-wise comparisons of functions and olive management, respectively. In the erosion evaluation case, the ANP method was used instead of the AHP, making it possible to consider the interactions among factors to determine the corresponding map.

Keywords: olive plantations, AHP, ANP, GIS, land use optimisation.

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ЗАГАЛЬНОВІДОМІ ПЕРЕВАГИ ТА СУБ'ЄКТИВНІ ДАНІ ЕКСПЕРТІВ В ОПТИМІЗАЦІЇ СІЛЬСЬКОГОСПОДАРСЬКОГО ВИКОРИСТАННЯ ЗЕМЕЛЬ

Метод процесу аналітичної ієрархії (ПАІ) був використаний для оцінки переваг громадян щодо функцій плантацій маслини європейської (Olea euroраеа L.) в гірській місцевості. За відповідями населення, найбільш цінні функції – це збереження населення в сільській місцевості (24 %), виробництво оливкової олії (18 %), попередження пожарів (17 %), скорочення ерозії ґрунтів (16 %). Загальна модель систем географічних даних (СГД) показує, що дві третини традиційної продукційної системи слід переключити на інтегровану й біологічну підприємницьку системи, а також відновлення середземноморського лісу.

Ключові слова: плантації маслини європейської, процес аналітичної ієрархії (ПАІ), процес аналітичної мережі (ПАМ), система географічних даних (СГД), оптимізація використання земель.

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ОБЩЕСТВЕННЫЕ ПРЕДПОЧТЕНИЯ И СУБЪЕКТИВНЫЕ ДАННЫЕ ЭКСПЕРТОВ В ОПТИМИЗАЦИИ СЕЛЬСКОХОЗЯЙСТВЕННОГО ИСПОЛЬЗОВАНИЯ ЗЕМЕЛЬ

Метод процесса аналитической иерархии (ПАИ) был использован для оценки предпочтений граждан касательно функций плантаций маслины европейской (*Olea europaea* L.) в горной местности. По ответам населения, наиболее ценные функции – это сохранение населения в сельской местности (24 %), производство оливкового масла (18 %), предотвращение пожаров (17 %), сокращение эрозии почвы (16 %). Общая модель систем географических данных (СГД) показывает, что две трети традиционной продукционной системы следует переключить на интегрированную и биологическую производственные системы, а также восстановление средиземноморского леса.

Ключевые слова: плантации маслины европейской, процесс аналитической иерархии (ПАИ), процесс аналитической сети (ПАС), система географических данных (СГД), оптимизация использования земель.

The production system management of olive plantations (*Olea europaea* L.) in Southern Spain is analysed from an economic, social and environmental perspective. The economic approach addresses the viability of the farming activities, the social criterion aims to prevent population loss in rural areas, whereas the environmental analysis involves the consideration of the reduction of soil erosion, the improvement of ecological diversity, the control of fire risk and the provision of quality agricultural landscapes.

In recent years, the driving force of the observed changes in the management of these agricultural systems, mainly from conventional management to agricultural land abandonment in mountain areas, is the implementation of the CAP reform of 2004 (Council Regulation (EC) No 864/2004) which entitles farmers to a fixed payment irrespective of their olive oil production[1]. The socio-economic and environmental consequences of these changes have been underestimated since more than 20 per cent of the Spanish olive plantations, mainly located in steeply sloping landscapes, will be better off leaving the farming activity since their low yields do not cover their higher production costs. Only in South Spain it has been estimated that an area of 220.000 ha is at risk of abandonment (Guzmán-Álvarez and Navarro-Cerrillo, 2008).

Since in most cases these agricultural mountain areas neighbour Protected Natural Parks, like the case presented in this study, their environmental functions, and the risks derived from agricultural abandonment (MacDonald et al., 2000), must be taken into account in order to determine which type of management, including a controlled abandonment, meets what Society demands on the one hand and the profitability of farming on the other.

In the present study the optimization of the agricultural land use integrates Society's preferences for the commercial and non-commercial functions of the olive plantations in mountain areas and the subjective experts' opinion about the suitability of the alternative agricultural system management to achieve these functions into a Geographical Information Systems (GIS).

Although this integrated approach is common in multiple land use optimization exercises (Stewart et al., 2004; Tait et al., 2004; Hajkowicz et al., 2005; Vold, 2005; Sikder, 2009), it is less frequent in agriculture (Santé and Crecente 2007; Gerber et al., 2008; Santé-Riveira et al., 2008; Sadeghi et al., 2009) and even more rare when the landscape component and other environmental issues are simultaneously considered (Tixier et al., 2008).

Other work that deals with the assessment of three different olive growing systems is Parra Lopez et al. (2008). Although this work dose not takes in to account a territorial dimension of the problem, it considers the mayor part of the function of the olive growing systems under three different scenarios.

The main purpose of the present work is social optimization of the olive farming area in the Montoro municipal territory (Andalusia, Spain). This optimization could serve for the local administration as a support guide to allocation of subsidies and corrective measures. To achieve this purpose the following exercises was carried out: *i*) six main functions performed by olive farming were selected; *ii*) the selected functions was evaluated by the local population via the AHP questionnaire (480 respondents); *iii*) at the same time several territorial models were made that evaluate the performance of the area with respect to each function under consideration; *iv*) the expert opinions about the performance of each

[1] This fixed payment accounts for 95% of the subsidies received during the base period under the former production-linked scheme.

alternative with respect to the selected function were collected; *v*) finally each of four considered alternatives and its most suitable allocation were evaluated.

The paper is organized as follows: Firstly, the study area, a typical Mediterranean mountain area covered almost entirely with olive groves, and the methodology followed in the study are presented. Secondly, based on the opinion of Society and several groups of experts, the territorial and general models are obtained and discussed. Finally, some conclusions are outlined.

AREA OF STUDY

The municipality of Montoro is located in the province of Cordoba in Southern Spain (Figure 1). The territory enjoys typical Mediterranean continental climate conditions with irregular precipitation distribution during the year (less than 600 mm/year). The Municipality of Montoro represents a variety of agricultural ecosystems (pasture, olive groves and annual crops) and forest/shrub natural vegetation near agricultural areas. Its 58,103 hectares are divided into olive plantations (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%).

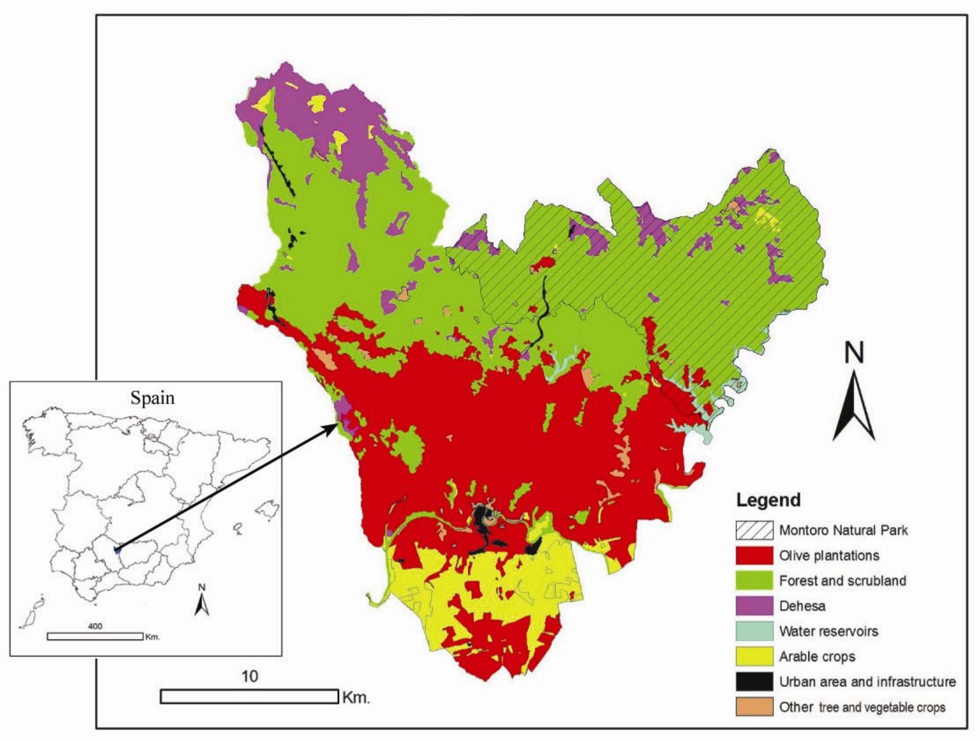

Fig. 1. **Study area map**

MATERIALS AND METHODS

1. Phases of the study

In order to assess the optimum agricultural system management (conventional, integrated, organic or restoration toward Mediterranean forest) for each pixel (the raster format of GIS analysis has been used) of the territory five phases were carried out:

1. Selection of most important socio-economic and environmental functions of these agricultural systems in mountain areas.
2. Preparation of the hierarchy structure of the study.
3. Evaluation of Society's preferences for these functions (their weightings in the general optimisation model).

4. Assessment of how each type of management contributes to achieving the selected socio-economic and environmental functions.

5. For each pixel, assessment on a 0-1 scale of its current suitability for each function. This phase produces five partial optimisation maps, one for each objective (production of olive oil, suitability for wildlife and flora habitat restoration, erosion risk, wildfire risk and visual impact).

6. Integration of the five maps into one which indicates for each pixel of the territory the optimum agricultural system management.

2. Primary data

The primary information gathered to implement the general optimisation model corresponds to the first four aforementioned phases and involves the following activities:

1. A focus group on the main functions provided by olive plantations in mountain areas. A group of experts on olive agricultural production and environmentalists ranked the main socio-economic and environmental functions of this agricultural system.

2. A survey in the province of Cordoba following a quota sampling based on sex, age and size of the municipality with quota sample size chosen by proportional allocation. Although this is a non-random sampling technique it often produces very good results in opinion surveys (Barnett, 1997).

3. A group made up of 15 experts assessed how the agricultural system management of the olive plantations (conventional, integrated and organic) or the abandonment of the agricultural activity and its restoration toward Mediterranean forest contribute to the achievement of the selected socio-economic and environmental functions. In order to attain a consensus a Delphi method was followed.

4. Three groups of experts assess the suitability for wildlife and flora habitat restoration, the wildfire risk and the erosion risk of the territory, respectively. The first two groups followed a typical Analytic Hierarchy Process (AHP) questionnaire, the last group of experts, the one assessing the erosion risk, expressed their opinions using the Analytic Network Process (ANP), a refinement of the AHP which allows for interactions among factors.

3. The AHP and ANP methods. Aggregating group opinions

Initially AHP was devised only for individual decision-making. However, after the multiple use of this method in different areas it was extended to group decision making (Aczel and Saaty, 1983; Dyer and Forman, 1992; Ramanathan and Ganesh, 1994; Gass and Rapcsák 1998; Lai *et al.,* 2002). In the present study this method is used to aggregate individual opinions of the local inhabitants and the experts' judgment upon the effects of the agricultural production systems on the selected objectives. In both cases the geometric mean was used (Forman and Peniwati, 1998).

4. The Geographical Information Systems (GIS)

The analysis of the area of study on a territorial basis involves the use of GIS, which is defined as an information system for the management and analysis of geographical information, and the geographical information as an abstraction or representation of the real world (landscape) (Georgiadou et al., 2004; Santiago, 2005).

The GIS software used as a platform for the representation, management and analysis of the spatial information was ArcGis 9.1 (ESRI) and ILWIS 3.4 Open with the SMCE module (ILWIS 3.4 and SMCE module was developed in ITC (Netherlands). This is free Software available at: www.itc.nl). The SMCE module makes it possible to manage and solve spatial multicriteria decision making problems. The input data were: land use map (1999; 1:50,000) corresponding to the study area (EGMASA, 2001); aerial monochrome orthophotos (2001-2002; 1:5000) and colour orthophotos (2005; 1:10,000); yield map of the olive plantations (2004; 1:25,000); road infrastructure map (1999; 1:25,000). The materials were provided by the Cartography Service (Junta de Andalucía, 2004, 2005). All geographical materials are represented in European Datum 1950, Zone 30N (Spain and

Portugal). Several trips to the study area were made with a GPS device, in order to check and if necessary, correct, the accuracy of the geographic information.

Empirical studies that have used multicriteria evaluation methods for the solution of spatial problems include that of Carver (1991) and later Malczewski (1999), which brought together two approaches developed much earlier: Multi-Attribute Utility Theory (MAUT) and the use of GIS as a platform for representing the spatial dimension of the problems. A large number of studies have since adopted this approach, including Hoctor et al. (2000), Store and Kangas (2001), Tseng et al. (2001), Thirumalaivasan et al. (2003), Ayalew et al. (2005), Strager and Rosenberger (2006), and Neaupane and Piantanakulchai (2006), this last dealing with different fields of the landscape assessment process.

As an example of the use of AHP for solving spatial problems, Thirumalaivasan et al. (2003) predicted areas that are more likely than others to become contaminated as a result of activities on or near the land surface. The AHP method computes the ratings and weights of each criterion on the parameters of the model. Then GIS software provides the spatial representation of the optimum solution. Similarly, Ayalew et al. (2005) deal with landslide hazard area prediction using both the AHP and logistic regression techniques. The results compare two susceptibility maps. According to these authors, the AHP map was closer to capturing the reality on the ground than the logistic regression. Strager and Rosenberger (2006) focus on the identification of high-priority areas for land conservation. For this purpose, individual stakeholders and expert judgements were combined using the AHP. A recent study by Neaupane and Piantanakulchai (2006) determined landslide hazard zonation but, unlike Ayalew et al. (2005) using the ANP method.

5. General optimisation model and territorial models

The solution of each AHP multicriteria problem involves the construction of the hierarchy of the objectives and the alternatives. Thus in the present case, a complex hierarchy was constructed (Figure 2) consisting of 5 levels.

Levels 1, 2, 3 and 5 are common to all AHP problems. Level 4 represents the inclusion of the territorial dimension of the analysis. At this level five territorial models are obtained to assess either the potential or risk of the olive plantations with respect to the functions demanded by Society: (1) Production of olive oil (the objective of keeping population in rural areas is considered as an non-territorial); (2) Provision of quality landscapes; (3) Suitability for wildlife and flora habitat restoration; (4) Soil erosion risk evaluation; and (5) Wildfire risk evaluation. The last three each required a group of experts in order to assess the effect of the landscape elements, natural and man-made, on its corresponding objective.

5.1. Visibility analysis of the study area

In the general model the visual quality of the alternative land uses is weighted depending on its visibility (Sevenant and Antrop, 2007; Hernández et al., 2004), therefore the aesthetic value of the agricultural land is increased in highly visible areas and, conversely, decreased in areas with lower visibility. The visibility analysis through an AHP questionnaire included both intrinsic and extrinsic elements (Martínez-Vega et al., 2000; Martínez-Vega et al., 2003).

5.2. Analysis of potentiality of the area for wild flora and fauna restoration

Mountainous agricultural areas with a high probability of being abandoned could be used for wildlife habitat restoration. However, there is a problem of how to evaluate agricultural land in terms of its suitability for wildlife habitat restoration. The competition between agriculture (particularly intensive agriculture) and wildlife habitats has been pointed out by several authors (Donald et al., 2006; Osinski, 2003; Santelmann et al., 2006; Waldhardt, 2003). The negative influence on wildlife habitats of agricultural activities through the use of agrochemicals and the modification of natural habitats has also been well documented (Pimentel et al., 1992; Sullivan and Sullivan, 2006).

It is clear that some indicators are needed for ecological diversity and wildlife habitat assessments of agricultural areas. Most of the indicators that have been developed to assess biodiversity and ecological diversity refer to species richness and the habitat requirements of particular species (Büchs, 2003; Duelli and Obrist, 2003; Jeanneret et al., 2003). The approach proposed focuses on one key species or "umbrella species", the Iberian lynx (*Lynx pardinus*). The Iberian lynx is included in the Annex of the Habitat Directive 92/43/EEC as a priority species. Currently the Iberian lynx is the most seriously endangered species of all the felids, and is recognized as critically endangered by the World Conservation Union (IUCN, 2002), and as the most threatened carnivorous species in Europe (Nowell and Jackson, 1996; Delibes et al., 2000; Guzmán et al., 2004). It is on the brink of extinction due to a low total population and a highly fragmented distribution (Rodríguez and Delibes, 1992, 2002; Fernandez et al., 2003; Fernandez et al., 2006). Its distribution is restricted to the Iberian Peninsula.

The method used involved three phases (Nekhay and Arriaza, 2009):

- first, an inventory of Iberian lynx habitat requirements was drawn up;
- then, the AHP method was implemented based on ten experts' knowledge;
- finally, GIS technology was used to assess the potential of the study area for Iberian lynx's habitat restoration.

This approach is similar to used in Nekhay et al. (2009b) where four regionally important wild species was considered.

5.3. Soil erosion risk evaluation

The Revised Universal Soil Loss Equation (RUSLE) factors (Wischmeier and Smith, 1978; Renard et al., 1997) were adapted to local olive growing systems in Montoro, with the addition of the proximity factor of rivers and streams and the expertise-based ANP evaluation. In contrast to the classic USLE/ RUSLE models, which assume that the factors are independent, the model proposed here allowed us to consider possible interdependences and feedback between factors. The factors considered were (Nekhay et al., 2009a): rainfall-runoff, grass vegetation cover, soil erodibility, river and stream proximity, slope steepness and slope length.

5.4. Wildfire risk evaluation

The abandonment of the agricultural activity implies higher risk of wildfires. As the area of study is adjacent to a Protected Natural Park, home of the world most endangered feline species, the Iberian lynx, this issue is particularly important.

The approach used for wildfire risk evaluation is based on AHP method with experts' evaluations and several indexes developed in different countries: the Canadian Forest Fire Danger Index (Lee et al., 2002), the Australian Forest Fire Danger Index (CSIRO Forestry and Forest Products 2000), the New Zealand experience (Leathwick and Briggs, 2001) and the National Fire Danger Rating System of the US Forestry Service (Deeming et al., 1978). The study of Gouma and Chronopoulou-Sereli (1998) was also considered.

5.5. Olive oil production

This map is a simple reclassification of the average olive oil production of the study area. Six categories of olive oil production (≤1000; 1001-2000; 2001-3000, 3001-4000; 4001-5000; >5000 kg of olives / ha) from a four-years time-series were calculated.

5.6. General model

In the general model the public's preferences about the functions that this agricultural system should provide to Society, the contribution of each agricultural management type and current suitability/risk of the territory for each function are mathematically integrated as follows:

$$U_{n,g} = \sum_{i=1}^{6} A_{gi} \cdot P_i \cdot F_{ni}$$

Where n represents each pixel of the study area (10x10 m); g is the type of management (conventional, integrated, organic and restoration toward Mediterranean forest); A_{gi} represents the adequacy of management g with respect to the function i; P_i is the weight given by Society to the function i; F_{ni} is the value that function i takes in pixel n (Figs 3 to 9).

Finally, the recommended management type for each pixel of the olive plantations, its socio-economic and environmental optimum (O_n) corresponds with the highest utility, mathematically: $O_n = \text{Max}\ (U_{n,1}, U_{n,2}, U_{n,3}, U_{n,4})$.

RESULTS AND DISCUSSION

1. Society's opinion about the functions of the olive plantations in mountain areas

A total of 480 citizens were interviewed following a structured questionnaire with AHP pair-wise comparison of the selected functions of the olive plantations. The aggregation algorithm produced the general preferences of Table 1.

Table 1

Social preferences of the functions of the olive plantations in mountain areas

Socio-economic functions (42.5%)	Keeping population in rural areas	24.2%
	Production of olive oil	18.3%
Environmental functions (42.2%)	Wildfire prevention	17.1%
	Soil erosion prevention	16.2%
	Wildlife and flora habitats improvement	8.9%
Provision of quality agricultural landscape (15.3%)	Olive plantations with vegetal cover between trees	6.4%
	Olive plantations colonized by Mediterranean vegetation	6.2%
	Olive plantations without vegetation between lanes	2.7%
	Total	100.0%

Source: Survey on social preferences carried out in Cordoba (Spain) with 480 personal interviews.

According to these results, the socio-economic and environmental functions should have equal importance in the optimisation of the agricultural land use. Notwithstanding, the aesthetic value of the agricultural systems should be taken into account as well in the territorial analysis.

2. Contribution of each olive production system to the selected functions

Conventional production systems imply high use of agrochemicals and tillage. In organic olive plantations industrially synthesised agrochemicals are not allowed and weeds are controlled by either mechanical techniques or livestock. The integrated alternative is a technical in-between solution which aims to regulate the type and dosage of agrochemical with minimal yield reduction.

Following the iterative Delphi method and AHP questionnaire, a group of 15 experts on agricultural production, agricultural economics and environmentalists assessed the contribution of each agricultural production system or its restoration toward Mediterranean forest to the achievement of these functions. The following table 2 shows their aggregated responses.

Table 2

Contribution of alternative land uses to the achievement of the selected functions

Function / Alternative	Production of olive oil	Keeping population in rural areas	Improving wildlife and flora habitats	Prevention of soil erosion	Prevention of wildfire	Provision of quality agricultural landscapes
Restoration	0.05	0.06	0.46	0.36	0.06	0.51
Conventional	0.33	0.33	0.05	0.07	0.42	0.09
Integrated	0.35	0.29	0.13	0.20	0.27	0.15
Organic	0.27	0.32	0.36	0.37	0.25	0.26
Total	1.00	1.00	1.00	1.00	1.00	1.00

Source: Survey carried out on 15 experts using an AHP questionnaire.

4.3. General model for the agricultural land use optimization

For each alternative management of the olive plantations the five maps are aggregated, as Fig 3 shows:

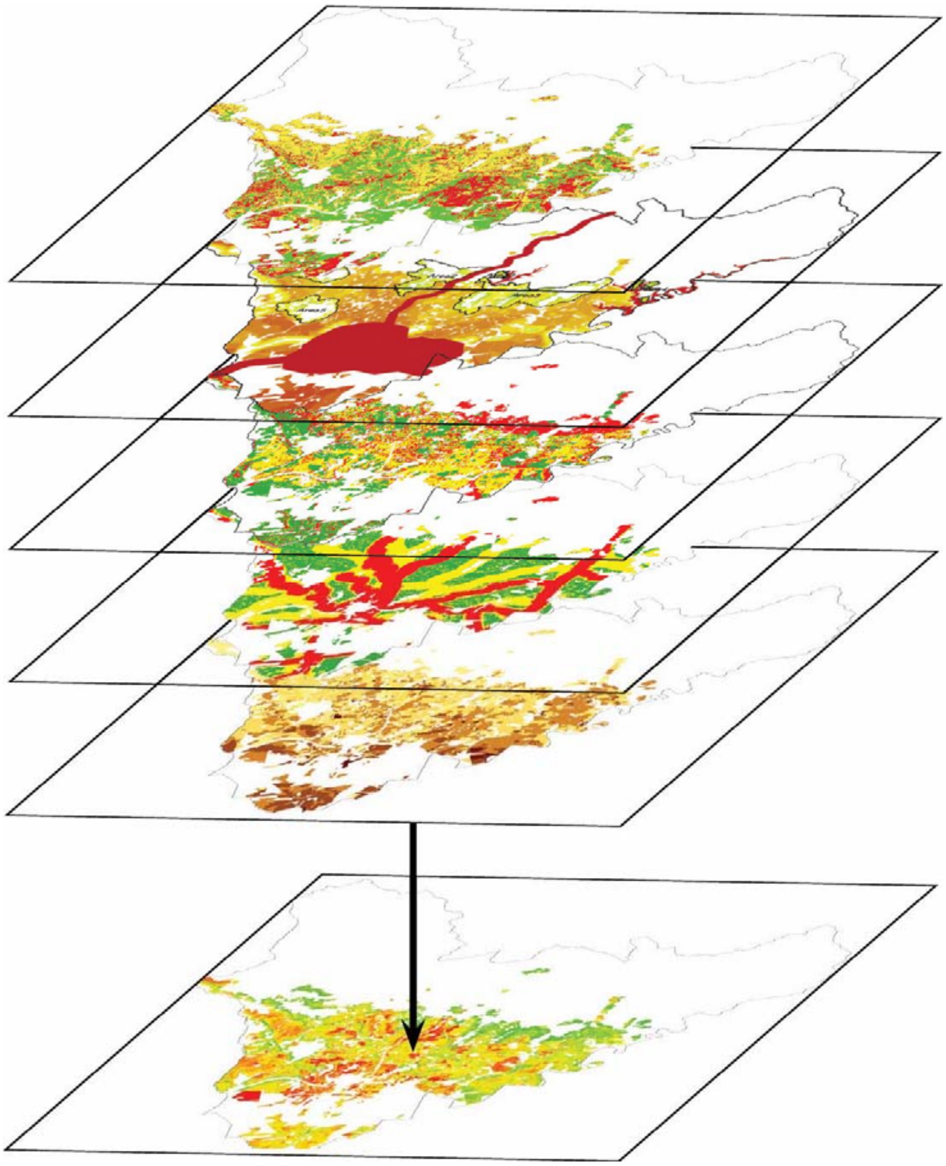

Fig. 3. **Weighed aggregation of the partial maps for each management type**

Once we have obtained the scoring of each alternative for each pixel, the highest value determines the optimum use. Fig 4 compares the current and optimum management type of the olive plantations in the study area.

The proposed changes imply a significant increase of the integrated and organic production systems to the detriment of the conventional system, as Table 3 shows.

According to these results, in order to promote a more sustainable agricultural system, taking into account Society's preferences and the experts' judgements about the effects of each agricultural management type and the suitability of the territory for the achievement of these functions, part of the conventional olive production system should be shifted toward either integrated or organic systems of production.

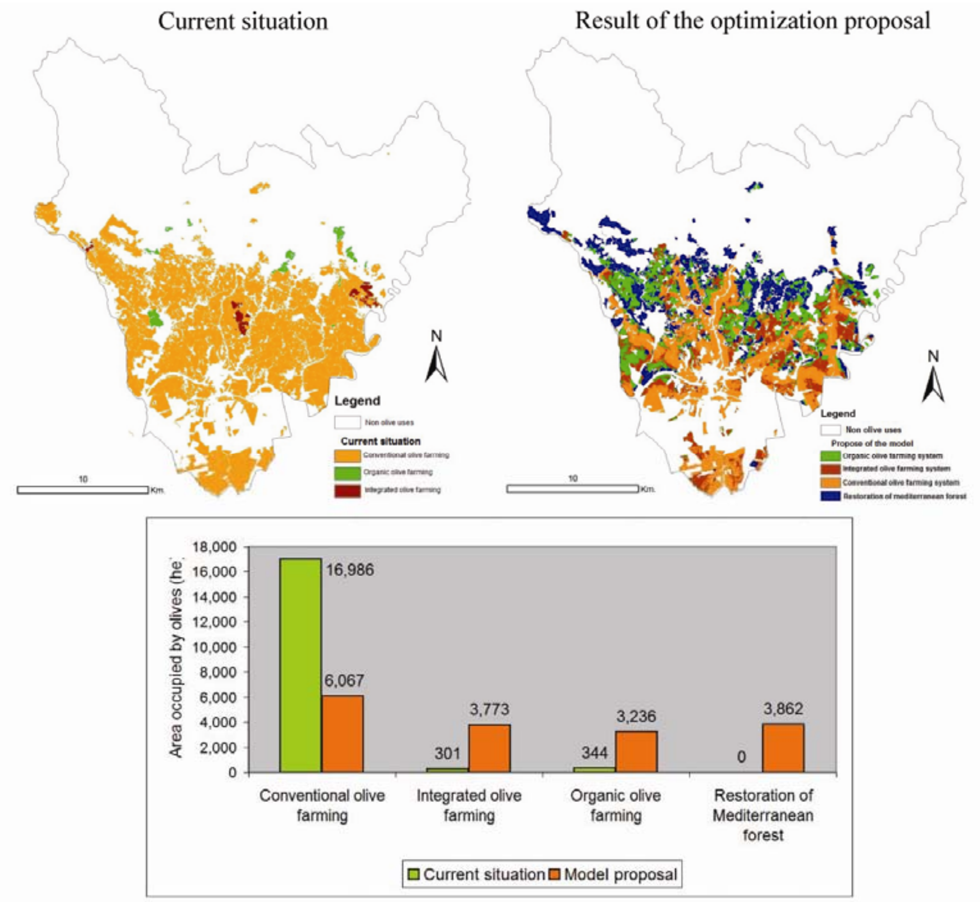

Fig. 4. **Comparison of maps of current and optimum management of the olive plantations**

Table 3

Current and optimised agricultural land use in olive plantations

Production system	Current situation (ha)	Optimised land use (ha)
Conventional	16,292	6,067
Integrated	301	3,773
Organic	344	3,236
Restoration to Mediterranean forest	0	3,862
Total	16,938	16,938

The upland olive growing systems represent a typical example of the unfavourable agricultural area that could be abandoned in the nearest future. However, these areas perform several socio-economic, environmental and landscape visual quality functions. That is why the intervention of the public administration is very important in order to prevent this uncontrolled abandonment of agricultural activities. Nevertheless, the public administration needs a scientifically sound tool that could help to support a decision to implement different agro-forestry systems in uplands areas. The study presented here shows one possible way to optimize the use of the olive growing area in agreement with the selected functions.

The main advantage of the proposed approach is the possibility of optimization of the agricultural land use embedding the opinions of the local inhabitants and the territorial dimension of the problem at low cost and in a reasonable time. The results of the optimization of the agricultural territory suggest the redistribution of the management systems currently in use in the olive plantations of Montoro toward a much more balanced situation. The use of Geographical Information Systems in conjunction with the AHP multicriteria decision making technique make it possible to locate which agricultural management is suitable in the territory.

The proposed changes in agricultural land use should have the financial support of the public administration. One example of the compensation payments is presented by Ulbrich et al. (2008) as specific software.

However, the commented advantages of this approach have several limitations. Firstly, it is highly sensitive to people's and experts' opinions. This problem could be solved through a dynamic model which updates changes in public opinion. This, however, should be done with caution since the proposed restoration measures must be planned over the long-term. Secondly, the use of the geographical boundaries in the submodels with clear limits instead of a fuzzy or soft consideration to model environmental processes represents an approximation to reality. Finally, an additional issue is the resolution of available digital layers: The land use map used is 1:50,000 spatial resolution and other digital layers used have 1:25,000 or 1:10.000 spatial resolution. This means that allowed spatial errors are from 10 to 50 m or even 100 m in some layers.

As a remark, some future research lines are being opened from this work. An obvious one is the consideration of other functions of the agricultural systems not considered in the present study. The design of a dynamic model able to include the time dimension of the problem and its influence on the ranking of the alternatives is a second one. Finally, to overcome the limitations of the AHP linear structure and its main assumption of mutual independence of elements at the same level and of different levels in the hierarchy, criticized by some researchers (Dyer, 1990; Holder, 1990; Barzilai and Golani, 1994; Leung and Cao, 2001), the Analytic Network Process could be applied instead.

CONCLUSIONS

In this paper (a) citizens' preferences for the functions that olive plantations in mountain areas should provide to Society and (b) experts' opinion about the suitability of each olive production system (conventional, integrated and organic) and the restoration of the olive plantations toward Mediterranean forest for the achievement of such functions, are integrated into a GIS to determine changes in the agricultural land use to optimise social welfare.

According to the population's responses, the groups of environmental and socio-economic functions have equal importance (42% each), leaving the provision of agricultural landscape with a weight of 15%. Individually, keeping the rural population in the villages (24%), the production of olive oil (18%), the prevention of wildfires (17%) and the reduction of soil erosion (16%) are the most valued functions.

In order to aggregate public and expert opinions we have used the AHP technique which makes pair-wise comparisons of functions and olive management, respectively. In the erosion evaluation case, the ANP method was used instead of the AHP, making it possible to consider the interactions among factors to determine the corresponding map.

The general model integrated the six functions that correspond with five partial maps (visibility analysis, habitat restoration for the Iberian lynx, soil erosion risk, wildfire risk, average olive oil production and keeping rural population, not considered as a territorial function) indicating via a GIS the either most suitable production system management or abandonment of the farming activity for each pixel of the study area. The results suggest that part of the conventional production management of the olive plantations should be changed to (a) Mediterranean forest in areas adjacent to the Natural Park, home of the Iberian lynx, and those near to rivers; (b) organic production management in steeped areas and high visibility areas; and (c) integrated production system, something in between conventional and organic systems, in steeped areas with higher yields. The conventional production system is most suitable for open plain with high yields and those near to roads to prevent wildfires.

The proposed changes would result in a higher level of social welfare due to the positive effects of the prevention of soil erosion, the expansion of endangered species' habitats and the preservation and improvement of the flora and wildlife in general. In addition, the higher ecological diversity improves the visual quality of this agricultural system.

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