Suitability assessment of olive plantations for Iberian Lynx habitat restoration

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Abstract— **This study adopts a twofold methodological approach to assessing the suitability of agricultural areas for wildlife habitat restoration. Embedding expert judgements through an Analytic Hierarchy Process (AHP) and Geographical Information Systems (GIS) about the effect of specific elements of the landscape on Iberian lynx (Lynx pardinus) habitat restoration potentiality as an indicator of selection of the most suitable agricultural areas to be transformed to the natural state (Mediterranean forest and scrublands). The case study is the olive (Olea europaea L.) plantations of the mountain areas of Andalusia (Spain) which, because of their low yield, are likely to be abandoned after the decoupling of the EU olive oil subsidies. The results suggest that the edge of major agricultural areas (mostly olive groves), the natural vegetation and areas adjacent to Natural Park with oaks would be most suitable for wildlife habitat restoration. These results are in agreement other studies carried out by other researchers on biodiversity, based on either individual or groups of species.**

Keywords— **analytic hierarchy process (AHP), GIS, Lynx pardinus, habitat restoration, Spain.**

I. INTRODUCTION

Marginal 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 marginal agricultural land in terms of its suitability for ecological diversity restoration. The competition between agriculture (particularly intensive agriculture) and wildlife habitats has been pointed out by several authors [1-4]. The negative influence on wildlife habitats of the agricultural activities through the use of agrochemicals and the modification of natural habitats has also been well documented [5,6].

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 [2,7-9]. This methodological approach was adopted in this study using the habitat requirements of the Iberian lynx (*Lynx pardinus*) for the evaluation of restoration potentiality of its habitat's in mountains olive groves of Montoro municipality (South of Spain).

Currently Iberian lynx is the most seriously endangered species of all the felids recognized as critically endangered by the World Conservation Union [10] and the most threatened carnivorous species in Europe [11]. It is now on the brink of disappearance due to low total population size and highly fragmented distribution. The Iberian Peninsula is its solo habitat.

There are a certain number of ways to provide the evaluation of habitat for wild species. These include Geostatistical Probabilistic Modeling [12], Scenario Modeling [4] and Multi-Criteria Decision-Making [13,14]. Within the last approach, we followed in the present study the Analytic Hierarchy Process (AHP).

The AHP technique uses expert judgments as inputs for weighing alternatives [15]. In our study, expert knowledge determines the relative importance of each criterion of the Iberian lynx habitat requirements.

II. THE AREA OF STUDY

The municipality of Montoro is located in the province of Cordoba in Southern Spain. The territory enjoys typical Mediterranean continental climate conditions with irregular precipitation distribution during the year (less than 600 mm/year). 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 (27.5%), arable crops (6.6%), forest and natural vegetation (37.5%), natural park (20.9%), Mediterranean pasture (6.7%) and other crops (0.8%).

We focus on the mountain olive groves located in the central part of the municipality. Such plantations play an important role in the Andalusian cultural landscape in addition to having an environmental value. Their low yields (less than 1,500 kg of olives/ha) will make them unprofitable after 95% subsidies have been decoupled. Currently this territory is a poor habitat for Iberian lynx, due to the continuous agricultural activities and the lack of herbaceous cover between the trees. Currently this territory is a poor habitat for Iberian lynx, due to the continuous agricultural activities and the lack of herbaceous cover between the trees. The return of parts of these plantations to their natural state could be one action to be undertaken.

III. METHODS

The methodology involves three phases: First, an inventory of Iberian lynx habitat requirements is drawn up. Then, the AHP method is implemented based on the experts' knowledge. Finally, the Geographical Information Systems technology is used to assess the potential of the study area for Iberian lynx's habitat restoration.

III.1. Selection of landscape elements related to Iberian lynx habitat requirements

Some authors claim that Mediterranean scrub-lands, forest and pasture are preferred habitats for Iberian lynx [16-17]. Indeed, the lynx takes refuge in forest and shrub vegetation, and catches its preferred food in areas of open pasture. Another important aspect is the "peacefulness" of the area: the lynx is very sensitive to the presence of human beings and to the habitat disturbance produced by any kind of human activity [18]. Although lynx generally try to avoid any contacts with humans, road traffic is regarded as an important cause of mortality and would be desirable to reduce the interactions here.

As an important contribution to the evaluation and modelling of the Iberian lynx habitat, we would like to mention a study carried out by Fernández et al [19] that considered seven landscape variables related to relationships between breeding territory distribution and landscape patterns, for different lynx populations. The main objectives of this study were: "to evaluate relationships between the presence of lynx species-specific landscape patterns in the Sierra Morena Mountains; to predict the amount of habitat available to the species in this area and its potential carrying capacity for lynx; and to assess landscape management needs for the conservation of lynx habitat". The final two objectives have some similarity with our study.

Following the revision of mentioned studies we selected the landscape components to be used in the present study. In accordance with reviews of the literature [16,23] we base our evaluation on the consideration of the zones of influence for each type of landscape object selected (except olive groves) (see Table 1).

Table 1. Landscape objects related to the habitat requirements of Iberian lynx

Landscape objects	Remarks
Urban areas	Main urban areas situated in the study area.
Asphalted roads	All asphalted roads existent in the study area.
Olive orchards with or without vegetation cover	Represents the study area subject of the evaluation, consists on the mosaic of agricultural plots with different type of agricultural practices (more or less intensive with or with out grass vegetation cover).
Currently existent vegetation formations	Mediterranean forest, scrubland, pastures.
Natural Park of Sierra de Cardeña and Montoro	The positive influence of Natural Park is considered.
Water bodies (stream, rivers, reservoirs)	Streams, rivers and reservoirs.
Influence of Urban areas	Constrain
Cordoba-Madrid high speed motorway (500 m area on the both sides)	Constrain
Ciudad Real motorway (250 m area on the both sides)	Constrain
Water reservoirs	Constrain

III.2. Analytic Hierarchy Process multicriteria decision-making technique

The Analytic Hierarchy Process (AHP), developed by Saaty [15], belongs to the family of multicriteria decision-making techniques. The principal interest of this method lies in the possibility of weighing conflicting objetives via pair-comparisons [20].

<u>Sample of the questions asked and group decision-making</u>

The opinion of ten experts on Iberian lynx behaviour was gathered through either face to face interviews or via email using the usual AHP questionnaire.

Before we started with the questionnaire we described (approximately 10 minutes) the objectives of the study and the meaning of each landscape object. In the case of e-mail interviews the main questionnaire was accompanied by explanatory information. Once all the responses had been collected and transformed to the weightings for each landscape object (see “Description of the AHP algorithm”) we interviewed each expert again, asking: “Do you agree with the relative value of each landscape object obtained from your answers?” Only if the response was positive we proceed to utilise the results of the interview. In cases of disagreement, the questionnaire was repeated, and the results re-confirmed. The confirmation procedure was necessary due to the high values of Consistency Ratio (Inconsistency) obtained by some of the questionnaires.

III.3. GIS-aided analysis

<u>Obtaining the resulting map through the overlay analysis</u>

The first step in the cartographic analysis is to verify the accuracy of the geographical information. For this purpose the input maps and aerial photos were compared. On the basis of recent aerial photographs, new highway and urban area were added, and some corrections to the size of olive groves were taken into account.

The next step was to reclassify the information presented in the land-use map. All existing land use types were classified into four groups: natural vegetation areas, olive plantations, urban areas, and reservoirs and lakes. The natural vegetation areas were subdivided on three classes: Mediterranean forest, scrublands and pastures. Other land uses such as rivers, streams and roads were treated as linear landscape structures. Non-olive agricultural land uses were not considered in the study. Olive plots were standardized according to management type (with or without grass vegetation cover).

A simple hierarchy structure with five criteria and four constraints (see Table 1) was built. We then used the reclassified land use map of the study area to generate the zones of influence surrounding the selected landscape elements (except the olive plantations). The next operation was the assignment of weightings to each landscape element. The weights were obtained through the expertise procedure described above. When all of these operations had been completed we performed a raster overlay analysis in order obtain the result map, in which the index value for each pixel is calculated.

The overlay analysis is provided via the linear weighted sum for classic AHP [15] and for Multi-criteria Analysis in GIS [21], as discussed above. The result is presented in raster format with a cell size of 10 m.

IV. RESULTS

Ten experts were asked for their evaluation of the importance of the landscape objects in terms of their influence on Iberian lynx habitat restoration. The weights derived from the experts' answers are shown in Table 2.

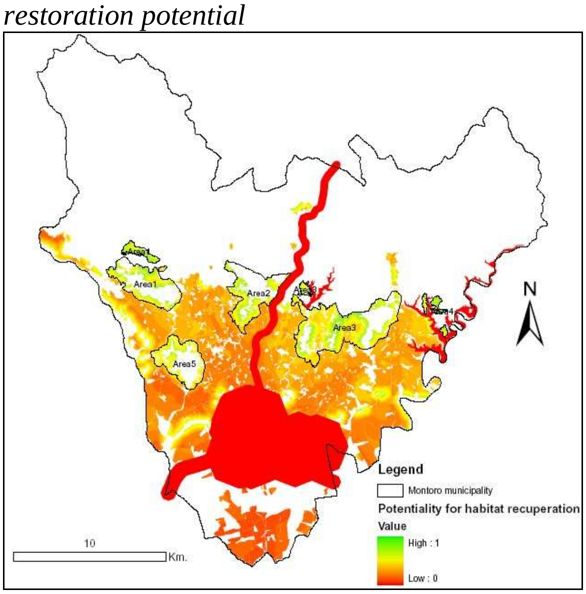
Significant differences were found between the answers of some experts. However the application of the geometric mean method [22] offers us the possibility to use the aggregated priorities of all the experts (Table 2). Thus, the most (32%), followed by proximity to asphalted roads (28%), followed in turn by proximity to the Natural Park (18%) and proximity to water (14%). Olive groves with vegetation cover obtained the lowest weighting (8%).

Table 2. Aggregated weightings of individual landscape objects

Landscape objects	Relative weights
Influence of asphalted roads	0.280
Olive orchards with or without vegetation cover	0.078
Influence of currently existent vegetation formations	0.323
Influence of Natural Park of Sierra de Cardeña and Montoro	0.182
Distance to water bodies (stream, rivers, reservoirs)	0.137
Influence of Urban areas	Constrain
Cordoba-Madrid high speed motorway (500 m area on the both sides)	Constrain
Ciudad Real motorway (250 m area on the both sides)	Constrain
Water reservoirs	Constrain

Among all the experts we can distinguish two opposite groups; experts 2, 3, 4, 7 and 8, who assigned very high importance to the influence of asphalted roads (at least 37%) and the other group of experts (1, 5, 6, 9 and 10), who assigned great importance to the influence of current types of vegetation (at least 41%). In the sensitivity analysis section we will consider the opinions of two experts representing the different groups.

Figure 1. *Evaluation of Iberian lynx habitat restoration potential*



The red area in the centre represents a zone that is negatively influenced by urban area and thus regarded as a constraint (non-compensatory criteria). The red lines that pass through the result map represent two motorways that have high levels of traffic. The maximum suitability value recorded in the study area was 0.86, the minimum was 0.14 and mean value was 0.49 (scale 0-1).

The result map highlights five areas with relatively high potential for lynx habitat restoration (see map Areas with high potential for lynx habitat recovery). These occupy a total area of 4,516 ha (Areas 1 to 5: 982, 874, 1830, 102 and 728 ha, respectively). Generally speaking, all of these areas are adjacent to water or natural vegetation and within the area of influence of the natural park. Yet, Area 2 is situated near one of main roads and would suffer from its influence.

V. CONCLUSIONS

The method presented here makes one important contribution: the use of landscape matrix elements as a criterion of the spatial Multi-Criteria decision-making problem for the evaluation of habitat restoration potential. The importance of each of the landscape elements considered was derived from expert knowledge. This type of procedure is less time-consuming than traditional models based on sampling and learning about key species requirements, while it can also be used for relatively large areas through expert knowledge models, which in some cases yield better predictions than historical data models.

A combination of the model presented here with models based on sample data for species habitat suitability would offer an interesting line for future research. Other such lines might involve utilization of non-linear functions such as multiplicative AHP. Consideration of the interdependences and feedback between the model criteria and negative priorities via Analytic Network Process would also be worth pursuing in future studies.

The results of this study coincide with others that emphasise the importance of the edge zones of major agricultural areas, the riparian zones (in our case their natural vegetation) and areas adjacent to nature pinewoods (in our case Mediterranean forest and shrub lands) as having the highest potential for biodiversity.

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