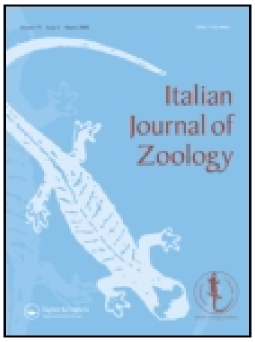

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Use of GIS to predict potential distribution areas for wild boar (*Sus scrofa* Linnaeus 1758) in Mediterranean regions (SE Spain)

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Abstract
The wild boar is the target species selected for developing a GIS model of potential habitat for big game species, mainly using many GIS layers and kilometric abundance indices (KAI). We identify and weight environmental factors that determine the suitability for wild boar populations in a Mediterranean region, highly influenced by urban and agro-forestry activities. Marina Baja region (Spain) is selected to make a regional analysis. In the GIS modelling process, a suitability value is assigned to each pixel, which represents the habitat preference of the species. In the potential habitat model some variables were considered, the most important being land use. Voronoi polygons are generated by calculating the centroid of census transects located with GPS. These polygons are combined with the 'suitability' layer to obtain potentiality values, involving the displacement of the wild boar impedances within each Voronoi polygon. Finally, it performs the cartographic generalization process to obtain the resulting potential areas. We have obtained six potential areas that represent 39% of the region and they are best for the species. Natural vegetation is the most important landcover type in these areas. The cost-distance model is an efficient tool that gives good results in line with existing knowledge of species distribution. The model is constructed in order to explain, understand and predict the relations of analysed species using a determinate number of environmental variables. Thus, the use of GIS has allowed the information coming from different sources to be integrated in a simple way, allowing wild boar observations (KAI) to be combined with the cost-distance analysis result.

Keywords: *Distribution, GIS modelling, land use, SE Spain and wild boar*

Introduction

Monitoring based on cooperation with hunters, managers of natural protected areas and wildlife management specialists is a good source of information for the study of mammals (Rosell et al. 1998, 2004). Interviews and surveys of the hunting managers and rural inhabitants provide an efficient source of information to obtain data on natural resources, especially wildlife and hunting species (White 2005; Jiménez 2007). Techniques used to model species distribution, when implemented in GIS tools, provide a wide dissemination of geospatial information (Ferrier 2002; Benito de Pando & Peñas de Giles 2007) and allow the modelling of their habitats (Park & Lee 2003). Moreover, Voronoi method permits to determine home range of the wildlife species (van der Ree & Bennett 2003).

The loss of natural habitat is so significant in the anthropized spaces that should be preserved natural zones, no matter how small is the area that they represent (Hodgkison 2005). By themselves, small patches cannot provide sufficient habitat for viable populations of many organisms, although they can have an ecological value (Fischer & Lindenmayer 2002a). Wildlife responds to the landscape structure at different scales. Some species are less vulnerable than others to habitat fragmentation (Fischer & Lindenmayer 2002a). They can therefore benefit from the protection of these fragments, embedded in an anthropized environment.

Anthropic uses have become a subject of Ecological Research to improve understanding of their impact and help minimizing it. Land development is generally recognized as a significant threat

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to biodiversity, being responsible for the decline and extinction of a large number of species (Marzluff & Ewing 2001). Thus, most biodiversity is lost irreversibly through an extinction process caused by natural habitat destruction (Colling 1996). In this way, urbanization is responsible for the elimination of original land uses, and therefore, home-range fragmentation and habitat loss (Marzluff & Ewing 2001).

Depending on local threats, some land uses can reduce the productivity and survival in adjacent habitats (Laurance 1997) or they can act as a buffer against external threats (Mesquita et al. 1999). Therefore, the urban matrix is not appropriate, but not radically inadequate to accommodate wildlife and vegetation. This leads to landscape conservation strategies in urban environments that must consider not only the size and quality of the patches, which act as habitat reserves, but also the nature and relationship between natural land uses and the urban matrix (Franklin 1993). In order to obtain a minimum guarantee of preservation, it is necessary to get an ecological value and determine the influence of anthropic elements in territory planning (Hodgkison 2005).

The wild boar is a species capable of settling in a wide variety of habitats. In the Iberian Peninsula wild boars are found from the forests of the Pyrenees to the dunes of the Guadalquivir River, including Mediterranean forest areas of the Southwest quadrant, Sierra Nevada, the Mediterranean coastal afforested pine, the humid ecosystems of Cantabria and Galicia or island forests that surround some cities (Rosell et al. 1998; Fernández-Llario 2005; Herrero et al. 2006). However, the wild boar abundance, in some Mediterranean areas, is affected by the landscape structure, especially in its diversity, so lowland and farmland limit its abundance (Acevedo et al. 2006).

Wild boar densities in Spain vary from less than one to 12 individuals per km^2, depending on various factors. The population trend of the species at present shows a considerable increase due to socioeconomic changes derived from the rural depopulation and the abandonment of traditional activities that have generated an increase in the forest and scrub surfaces and also agricultural intensification (Leranov & Castién 1996; Rosell et al. 2004). There are other factors such as the absence of predators, increase of food availability and the decrease in hunting pressure on the species (Leaper et al. 1999). The mean annual home range area for males is about 12,000 to 15,000 ha, and 6000 ha in females (Santos et al. 2004), but may be influenced by the hunting intensity (Boitani et al. 1994). The broad home range of the species makes it ideal for studies of potential and functional connectivity in large geographic areas, as in this region.

Specific management plans should be implemented in some areas because of the potential damage wild boar may cause to other game species and crops (Tellería & Sáez-Royuela 1985; Leránoz & Castién 1996; Rosell et al. 2004). Crops most affected by this species are maize, wheat and alfalfa (Herrero et al. 2006, Santos et al. 2006). The study of the wild boar demographic evolution is therefore of high interest to game management and for minimizing crop damage (Jiménez 2007). In addition, such study should focus on a particular species to define the parameters of the connectivity model, considering hunting collected censuses (Gross et al. 1995).

It is far easier to detect wild boar by its signs than by direct observation of individuals. Thus, most wild boar studies use indirect detection methods (Acevedo et al. 2006; Hebeisen 2008). In addition to the footprints and excrements, this animal leaves numerous and apparent traces in the environment, such as bathing places marked or rubbed trees, soil marks, beds and hair on the fences separating farms (Rosell et al. 2004; Jiménez 2007; Peña 2007).

The main objective of this study was to identify the environmental factors that determine the sustainability of wild boar populations in a regional area, highly influenced by urban and agro-forestry activities. Taking into account these environmental variables and using GIS (Geographic Information Systems), our aim is to build a habitat model in order to have an approach of the suitability habitat locations which allows the presence of this wildlife species. Other objectives considered in this paper focus on the source populations identification based on the size of land use patches, spatial context (different land use matrix) and habitat quality (different units combination). It is also the intention to define the landscape resistance value based on the species habitat requirements. This methodology has been used before in similar studies (Park & Lee 2003; Nikolakaki 2004).

The main contributions of this study are the identification, discussion and weighting of the variables and the interpretation of results relating them with the abundance data obtained from extensive field work. In addition, there are considerations in this study which are easy to extrapolate to other Mediterranean landscapes.

Study area

In the report issued in 2006 by the Spanish Sustainability Observatory about Spanish land use change, based on the Corine Project that identifies land uses and covertures in the European territory (Bossard et al. 2000), it can be observed that Valencia is one of Spanish regions with a greater territorial transformation rate in recent decades, not only in the structure and landscape dynamics, but also the spatial land use organisation (Martínez-Pérez 2000). This area is experiencing accelerated changes mainly due to the increasing development of coastal and inland areas, abandonment of traditional farming activities and expansion of modern intensive agricultural methods. Together, these changes are increasing the fragmentation of these landscapes (Serra et al. 2008). Thus, semi-arid landscapes may be more affected by these transformations as they are more prone to desertification (García-Ruíz et al. 1996; Lasanta et al. 2000).

The Marina Baja region is an example of the above mentioned pattern of change. It is located in the Southeast of the Iberian Peninsula, in the province of Alicante. As an administrative unit it covers about 580 square kilometres and it consists of mountainous and coastal sectors. It is composed of 18 municipalities, and Benidorm is the most populated and economically developed (Figure 1).

Elevation ranges from sea level to 1558 m in the Sierra Aitana, the highest elevation of the province of Alicante. With respect to hydrography, the rivers Guadalest and Algar, both stand out for their watersheds. Their flow rate has modules of 0.90 and 0.78 m^3/s, respectively (Solanas & Crespo 2000). It should be noted that the resources provided by this river system (Algar-Guadalest), supply most of the required water resources for this region. Amadorio-Sella hydrological system is also important but has a significantly lower modular flow.

The Marina Baja has a semi-dry Mediterranean climate, with mild temperatures, a prominent dry period in summer and rainfall concentrated in spring and autumn. The plant communities belong to the superior and inferior termomediterranean and mesomediterranean Thermo types (Rivas-Martínez & Usandizaga 2004).

In Marina Baja there are semi-arid, dry and subhumid regions with all gradients (Figure 2). The presence of different biotopes is characterized by important flora diversity. This territory is a good representation of the different landscapes in the province, from the mountains to the coast, including patches of padding and thorny oromediterranean vegetation, deciduous forest interspersed between sclerophyll forests, pine forests, thermophilic garrigues, salt and semi-arid steppe communities (Peña 2007).

Currently, the general distribution of land use is dominated by the natural matrix, followed by irrigated crops, abandonment crops, non-irrigated crops and finally urban areas (Arques et al. 2009).

It is important to note the gradual decline of non-irrigated crops, from 35% of the territory in 1956 to 10% at present (Arques et al. 2009). The loss of farmland is a consequence of the socioeconomic changes in Marina Baja. There has been an agricultural transformation from dry to irrigated crops and urban lands. Also significant is the growth of pine tree areas (mainly *Pinus halepensis*) and scattered holm oaks, which in 1956 was 18% of the land, rising to almost 30% today. Finally, artificial covers, principally urban land and infrastructures, have increased significantly rising from 2 km^2 to 42 km^2 in 44 years, but only around 7% of the zone (Peña 2007).

According to data provided by the hunting competent organism (CMAAUV 2007) there are a total of 21 game reserves with 2,060 hunters. The average hunter density is quite high, approximately 6 hunters/100 ha.

Materials and methods

Suitable areas are those that meet the requirements of a species, while the potential areas are those that our model predicts using a limited list of variables.

In order to calculate the potential areas we have created a GIS database, which includes 21 game reserves. The base maps used include the following variables: the game boundaries (CMAAUV 2007), environmental factors (land uses, topography, hydrology and road net) and field surveys (line transects) performed in this work.

GIS-Modelling

The GIS model developed to determine the permeability to the *Sus scrofa* advance is a cost-distance model. This approach is used for the management of other species (Schadt et al. 2002; Adriaensen et al. 2003). Also on the web page www.corridordesign.org it is possible to consult the cost-distance methodology and download useful tools for the software ArcGis 9.x® (Majka et al. 2007). In this work the tools of the spatial analyst extension of this software package have been used. We describe in detail the aspects of the GIS modelling as follow.

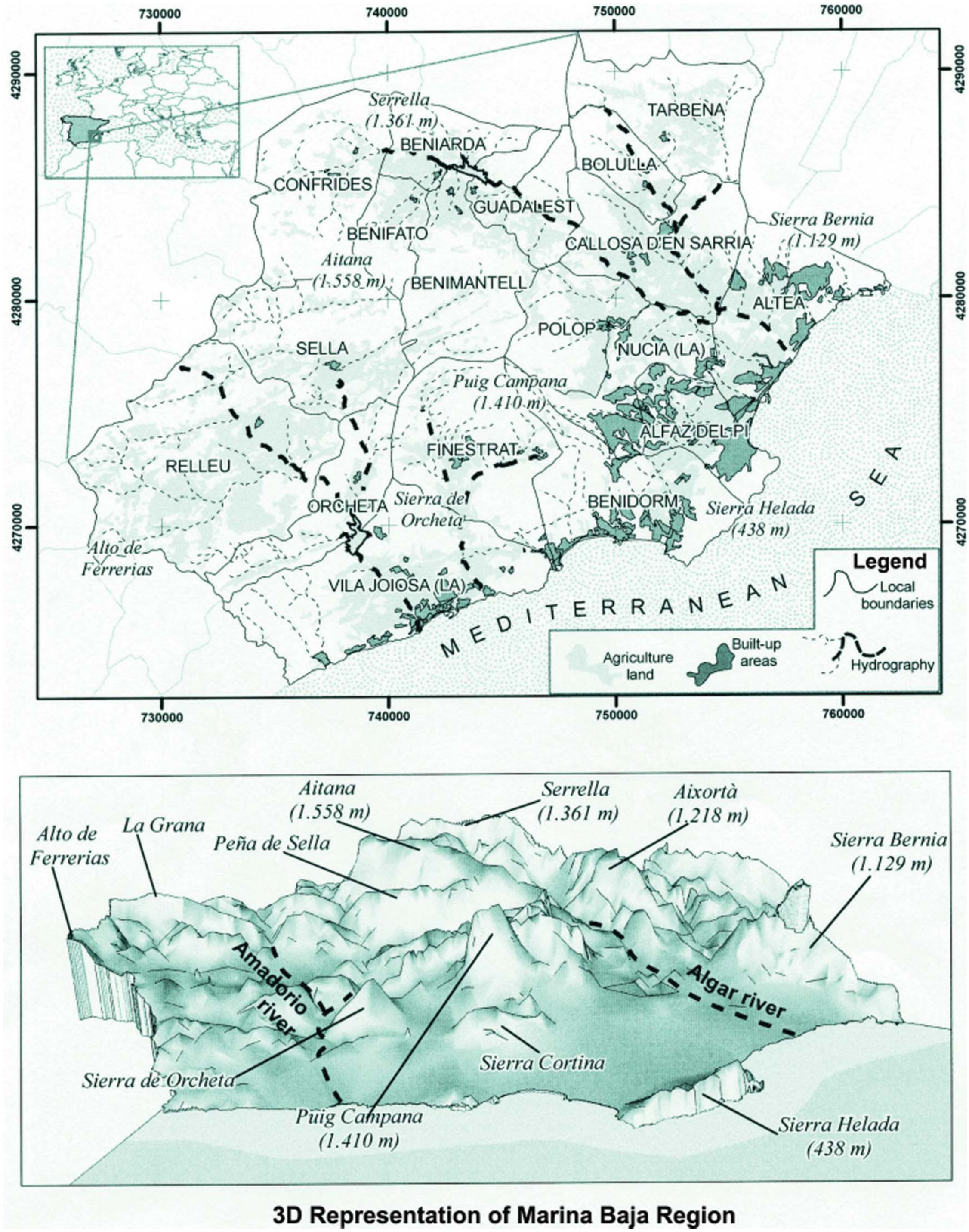

Figure 1. Description and 3D representation of the study area.

First step: choice of method

The method selected consisted in the creation of an impedances matrix against wild boar advance, for which knowledge of the habits and needs of this species was essential. This was obtained from the literature and from interviews to hunters, farmers and other inhabitants of the region. The species characteristics of interest to build the model have been highlighted in step 2.

The cost-distance model consists of the choice of different spatial variables that condition the permeability and their later weighting. Finally, we obtain

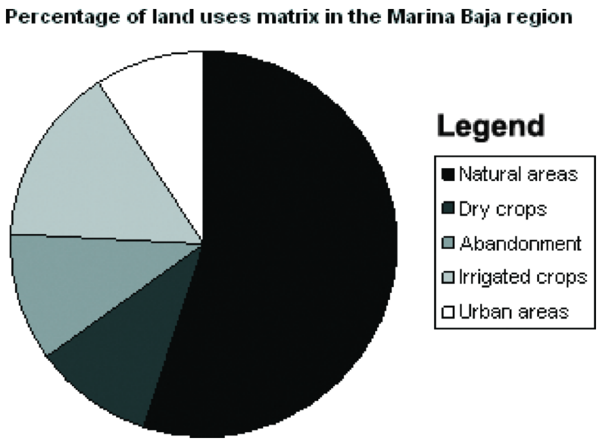

Figure 2. Land uses percentages in the Marina Baja (2007).

the cost matrix that theoretically it should indicate the areas that facilitate the wild boar advance across the landscape.

Second step: variables selection

Many habitat delimitation models, developed with GIS, include a series of variables relatively easy to create such as land uses, topography, water resources or the distance to anthropic elements (Vargas et al. 2006). Other variables such as study scale, lithology, soils or climate can also be included (Barbosa et al. 2003). Land uses are generally the most valuable layer in studies of habitat definition, because they provide an approach to landscape structure and the availability of food and other resources for wild boars (Keuling et al. 2008a).

Land use characterization has been carried out by the digitalization on screen of the study area on top of aerial photographs (ICV 2003). The land use layer includes 22 categories (Table 1), which are exported to vector and raster formats, to be used in the designing of the model. The approximate working scale is 1:5000. The photointerpreted land uses have been verified in the field along the field routes. To increase the detail of the land use classification and to save time, the land ownership cartography from the region was used (scale 1:2000), provided by the Land Registry of Alicante. This was used to define the localization of isolated houses, urban areas and communication roads. It was special interest AP-7 Highway which was mapped according to its boundary fence and not only according to the paved area (Figure 3). This type of infrastructure creates a physical barrier that hinders the natural movements of the species and the access to other potential areas. Besides, land uses have been used to calculate the Euclidean distance to the human elements.

For this study a Digital Elevation Model (DEM) was designed, using the cartographic base ODCV-10 from the Valencian Cartographic Institute at 1:10,000 scale (ICV 2007). From this DEM different measures and index descriptors of the territory morphology can be obtained. For instance, altitude, slope, orientations, ruggedness, landforms classification or topographical indexes can be calculated.

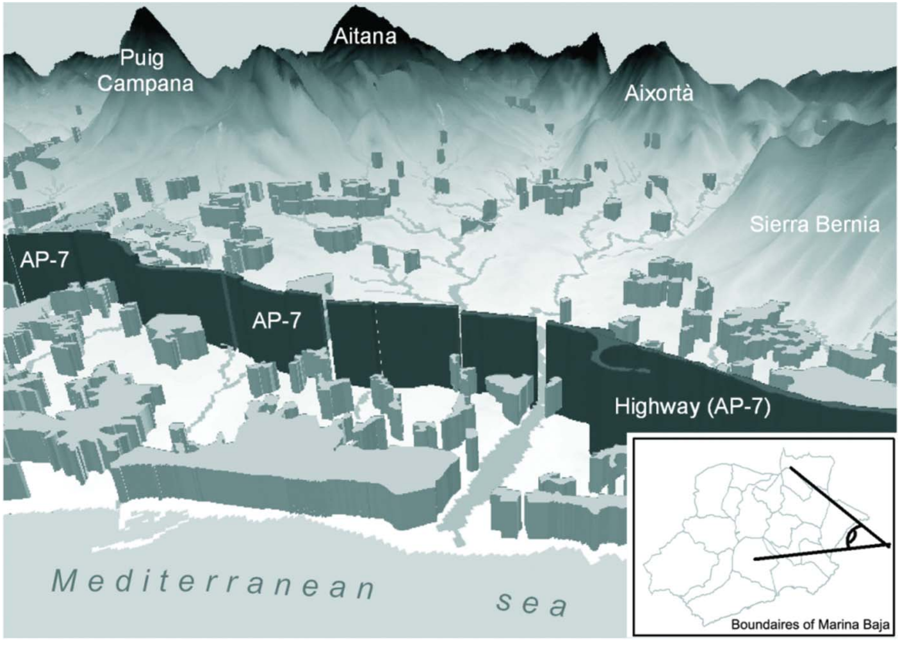

Figure 3. Main ecological barriers in 3D.

In our case, the altitude was chosen due to its influence in the food availability (Debernardi et al. 1995), Topographic Wetness Index (TWI) (Moore et al. 1991), since this is a very precise way to define the areas with better access to water resources, and it qualifies the rest of variables, much better than using the slope which would be a more useful variable when working at a bigger scale.

Topographic Wetness Index

Where TWI is the Topographic Wetness Index, "A" is the local upslope area draining through a certain point per unit contour length and "$\tan\beta$" is the local slope for that area.

Starting from the land use layer, the human elements that condition wild boar advance have been extracted. The distances to the transport network in general and particularly to the highway (AP-7), have also been considered. The AP-7 is not very permeables barrier to animal movements, because access is restricted and it is completely fenced in except for bridges and tunnels that allow vehicles and pedestrians to cross, as well as the wild boar. This condition of low permeability suggests digitizing the AP-7 in a discontinuous way (see Figure 3). The rest of roads have not been eliminated from the model, although the weighting, which is summarized in the following section, makes them not very advisable for wild boar presence. The distance to the communication network has been easier to estimate than density, which is the reason why the first of them has been used.

Third step: weighting the variables

In this section, the weight assigned to each one of the variables and their associated categories is included (see Table I), considering their influence on the target species. First, land use is related to

Table I. Selection and weighting of the variables and occupancy rate in the region.

Variable	Category	Weight	Occupation (%)
Land use (60/100)	Urban	0	7.61
	Dense pine forest	70	5.46
	Clear pine forest	50	11.88
	Olm oak	90	0.44
	Recent burned	20	0.72
	Forested scrubland	40	6.85
	Dense scrubland	40	13.31
	Clear scrubland	30	14.79
	Riparian	100	1.91
	Dry fruit	40	8.88
	Dry vineyard	40	0.49
	Cereals	40	0.54
	Irrigated fruit	40	7.53
	Irrigated vineyard	40	0.71
	Irrigated crop	40	2.55
	Recent abandonment	40	7.04
	Old abandonment	10	8.01
	Greenhouse	30	0.54
	Wetland	10	0.02
	Beach/dune	0	0.15
	Sea	0	–
	Main paved roads*	0	0.31
Elevation (5/100)	High (> 900m)	20	12.46
	Medium (90–900 m)	100	72.44
	Low(< 90 m)	20	15.04
Topographic Wetness Index (15/100)	High (> 8–22)	100	18.70
	Medium (> 6–8)	70	20.06
	Low (4–6)	40	45.59
	Very Low (< 4)	10	15.64
Distance to road network (10/100)	High (> 200 m)	90	35.78
	Moderate (> 50–200 m)	50	43.76
	Low (0–50 m)	30	20.45
Distance to water resources (10/100)	High (>200 m)	30	77.49
	Moderate (> 50–200 m)	50	15.79
	Low (0–50 m)	90	6.70

*: AP-7-Highway, national, regional and local roads.

food availability and refuge (Leaper et al. 1999), so it receives the highest weight in the model. In second place altitude which has a lower weight, because altitudinal thresholds are very lax and difficult to specify (Debernardi 1995), but it determines the availability of some resources (Baubet et al. 2004). WTI has been chosen to represent slope and water availability for vegetation. These aspects are relevant to species movements (Park & Lee 2003). The distance to the road network has also been considered, as the main human factor that affects habitat fragmentation (Keuling et al. 2008b). Finally, the vicinity to water resources has been included for its relevance for wild boar (Park & Lee 2003; Santos et al. 2004).

The weighting of each one of the classes included in the different variables is the result of detailed analysis of the relevant literature and the experience acquired in the field samplings (see Figure 5).

Fourth step: variables combination

Once the most explanatory GIS layers, according to previous knowledge, had been obtained, they were combined, using map algebra, like the pondered arithmetic mean of the five variables (see Table I). This combination method is simple and it gives the largest significance to the assigned values of each layer, allowing changes to be carried out and the combination to be recalculated in an easy way. Several tests were carried out using different variables weight combinations until the one most adapted to the species. The least appropriate spaces (urban uses and highway) were ignored to avoid their evaluation as appropriate areas (Figure 4).

The terms included in the rhombuses (elevation, roads, riparian and land use) are referred to the vectorial cartography. The rectangles show the raster cartography used (DEM, TWI, Riparian distance). The arrows indicate the direction of the processes carried out in the model calculation (rasterization, distances calculation, reclassifying and weighting).

The first matrix column, in raster format (see reclass grid in Figure 4), refers to the reclassification value while the second and third reflect the thresholds used for the reclassification. The maximum and minimum values of each raster layer are given in brackets. Following this procedure the five variables are obtained and reclassified with their corresponding weights. Finally, the sum calculation of the five variables in raster format (A+B+C+D+E) gives us the suitability values for the species. For example, a pixel with optimal value of permeability for this species would correspond to an area with the following environmental conditions: riparian vegetation, altitudes between 90 and 900 m, Wetness topographic index (8–22), located over 200 m to roads and less than 50 meters of water points.

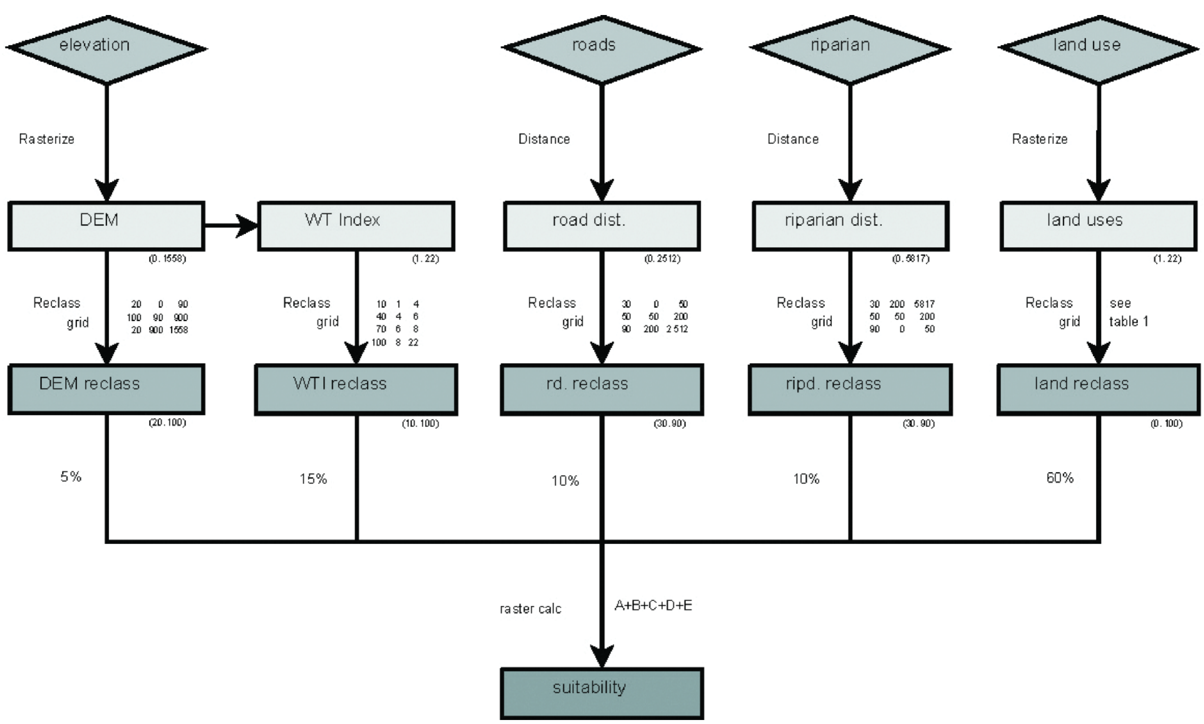

Figure 4. Processes carried out in the weighting of variables.

From the map created in the process of 'suitability', five classes of suitability index were identified. Figure 5 shows the total area percentages in the region for these categories. The areas excluded (8%) refer to urban areas or occupied by infrastructures, where the probability of occurrence of the species is very low. These areas have a pixel value less than 8.5. The most appropriate areas, with the habitat preferences of wild boar, account for 8% of the region. Best areas are identified in the model to offer cost-distance values above 49.5.

Field work

Once the main impedance raster map (cost-distance) was obtained, we clarified the model by overlapping it with the georeferenced field work. Wild boar relative abundances were obtained from 1000 m long (n = 42) stratified transects (Tellería 1986), conducted on foot along roads and forest tracks at dawn and sunset. These lines were recorded using a GPS unit. These transects were made, according to the typology of the landscape mosaic (Jiménez 2007), covering the diversity of land use matrices (natural, abandonment, dry and irrigated) and taking into account the contacts (individuals and signals) to have an estimated population in each census line (Table I). The samples were distributed seasonally taking into consideration the reproductive cycle (Gethöffer et al. 2007) and hunting periods (Jiménez 2007). Three sampling campaigns: post-game or pre-breeding (February), post-breeding (June) and pre-game (September), for three years (2006–2008) were carried out, with a total of 378 transects.

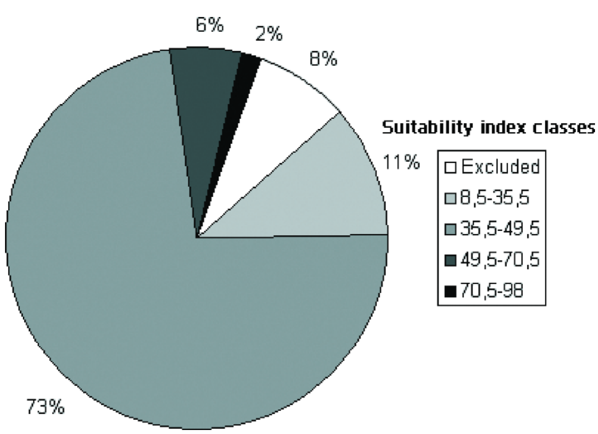

Figure 5. Suitability classes.

Wild boar abundance, in each of the land use matrices and sampling season, are presented by the Kilometric Abundance Index (KAI) (Ferry & Frochot 1958), expressed in number of observations per linear kilometre. We calculated the KAI means for each of the 42 routes from the KAI (n = 9) of the three census periods and years.

Overlapping field work data and suitability areas: definition of potential areas

Voronoi is the most appropriate method of interpolation, when the samples are highly aggregated and poorly distributed. This method allows accurate home range estimates, which forms the basis of some ecological analyses, including studies of habitat use determining spatial overlap of individuals, and for understanding behavioural patterns (Righton & Mills 2006). Moreover, it provided a rational basis for management decisions incorporating impact on species habitat (Qin et al. 2009).

In order to obtain the high potential areas of habitat, we use field work data joined to suitability data (see Figure 6). The most appropriated method to perform polygons with the same value, derived from transects, is Voronoi grouping. Voronoi polygons (KAI Voro.) are obtained from centroids (KAI centr.) calculated from transects registered with GPS (KAI GPS). Then, the spatial selection of the potential areas is carried out by overlapping the KAI Voronoi layer with the cost-distance (suitability layer). Finally, the shape of the patches is softened, eliminating interferences and obtaining the potential areas (see Figure 6).

We obtained a layer of information where wild boar sampling density can be seen (see Figure 7). In the GIS, the registered contacts in the field samplings

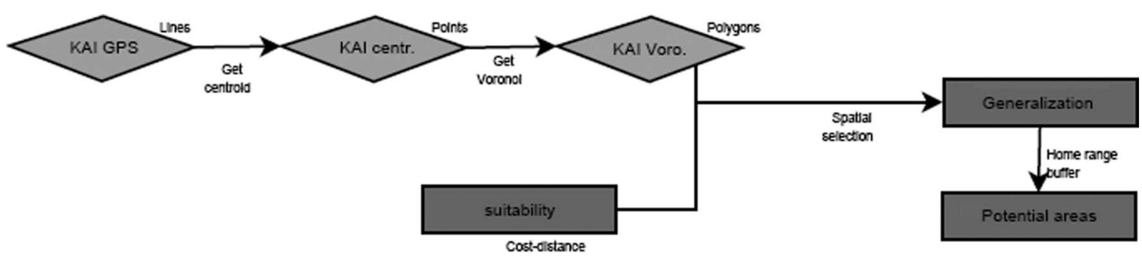

Figure 6. GIS modelling procedure to determine the potential areas.

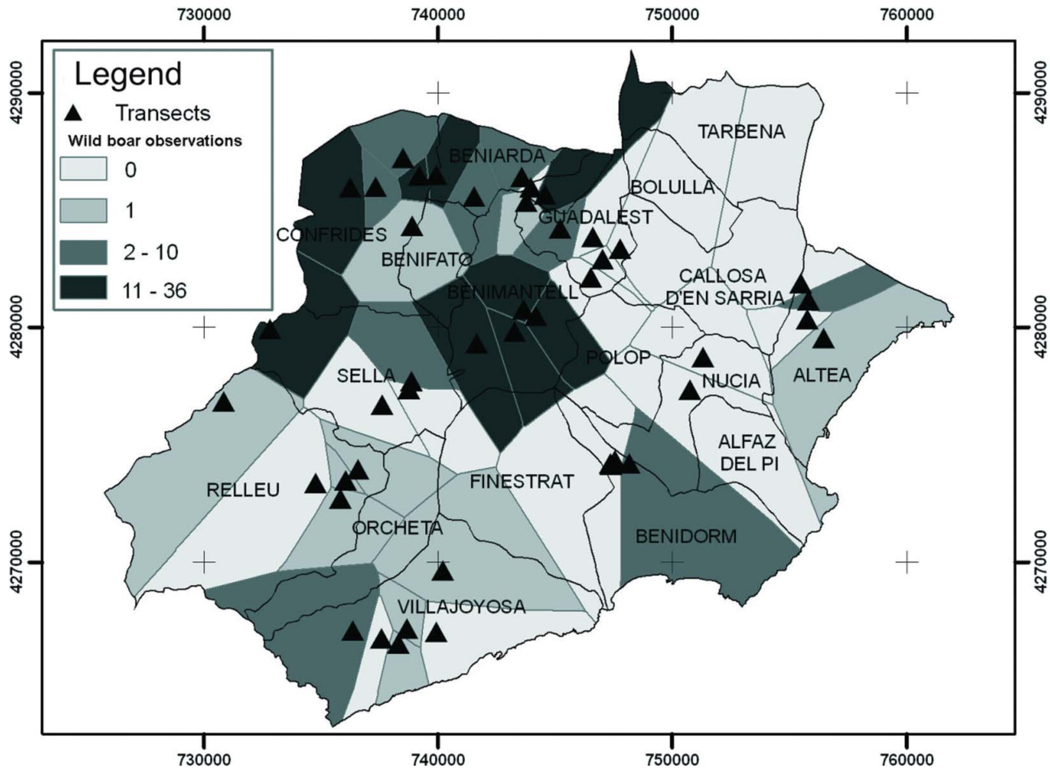

Figure 7. Distribution of wild boar observations associated to the Voronoi polygons.

are represented (KAI GPS) by associating this value to the surface defined by the Voronoi polygons (KAI voro.). Thus, we get an information layer in which we can appreciate the areas of influence of each category of KAI. Once the areas occupied by each class of KAI are defined, spatial selection is done to identify where the data overlap with Voronoi polygons (see Figure 7). This process is basic to be able to identify the larger potential areas for the species (see Figure 8).

Cost-distance analysis shows, as a result, many scattered patches in the landscape. These patches may lose their significance due to the large home range of the species (Keuling et al. 2008b). Therefore, a cartographic generalization method has been applied, where patches in the Voronoi polygon catchment areas have been grouped. Vectorization has been performed in areas that were widespread in raster format. Moreover, patches where the species was not present were discarded.

Results

The group of line-transects in the landscape matrix provides the following values of KAI means: abandonment fields (0.48 sightings/km), natural areas (0.76 sightings/km), non-irrigated crops (0.93 sightings/km) and irrigated crops (0.17 sightings/km). There are significant differences among matrices (Kruskal-Wallis chi-squared = 17.1069, df = 3, p-value = 0.0006719).

There are clearly six major patches within 'suitability' zones (see Figure 9). These six areas resulting from the process of generalization represent the most potential suitable habitat areas to accommodate the huge abundance of wild boar (suitability areas). The surface occupied in the region by the areas of potential presence is 22,609 ha (39% of total area). These zones differ in their percentages of land use, based on their geographical distribution (Figure 9). In all suitability areas, the dominant landscape matrix, in the generated habitat-suitability polygons, is composed of natural uses (45–70%). This aspect is essential for the suitability of an optimal habitat for the considered species. Furthermore, the presence of large patches of agricultural use (13–21%), or areas in a process of abandonment (9–20%) is important because they provide a complex landscape mosaic which facilitates the access to different resources (food and shelter). Drylands have been replaced by irrigated crops in the coastal area (9–19%), due to socio-economic factors. Finally, the coastal areas are characterized by a high percentage of urban land uses (26–27%).

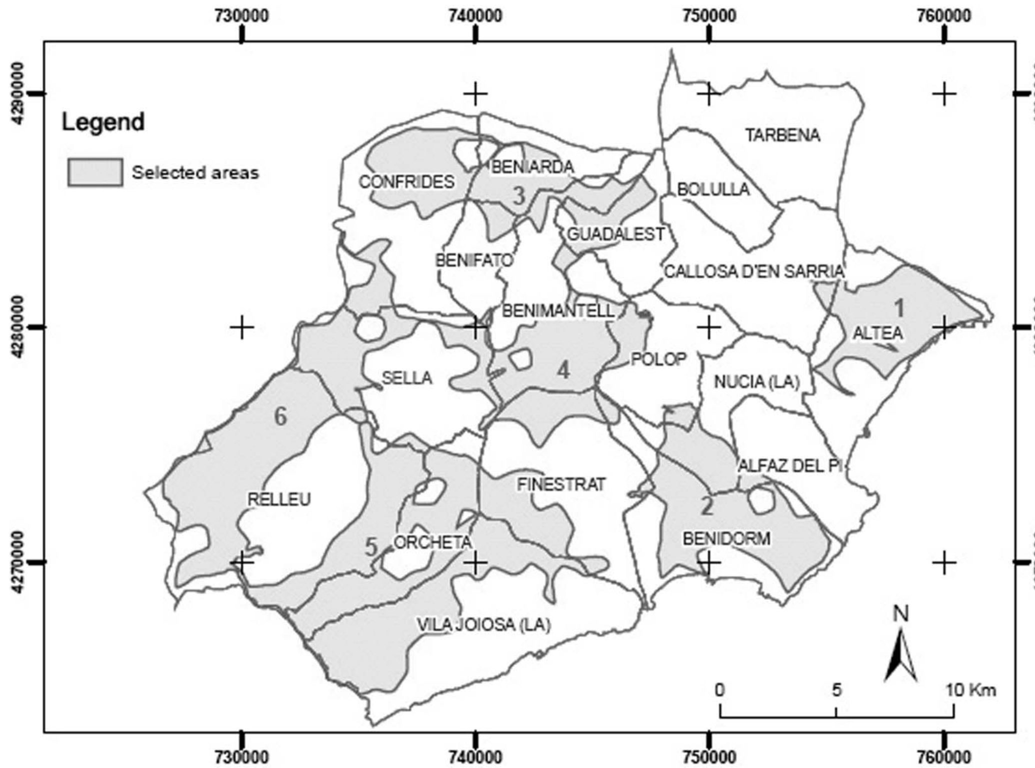

Figure 8. Areas of potential distribution for the wild boar.

The results of the cost-distance analysis show a great number of dispersed patches in the landscape. For this reason, a method of cartographic generalization has been applied, grouping patches within the area enclosed by Voronoi polygons. Generalized zones described above, created in raster format, have been transformed into a vector format. Then, all polygons, where presence of studied species had not been confirmed were removed. The surface occupied in the region by the areas of potential presence is 22,609 ha (39% of total area). Each of these zones differs in terms of land use with natural vegetation as the most important one.

Sampling effort was balanced across the study area, although as access was difficult in certain areas, in these areas the species detection was not as efficient. Cartographic validation with hunting surveys has revealed that the NE sector is an area with huge potential value, not included in the model. Data from hunting manager interviews indicate an abundant boar population in the nearby Bernia and Ferrer mountains.

Discussion

The use of GIS has allowed the information coming from different sources to be integrated in a simple way, allowing wild boar observations (KAI) to be combined with the cost-distance analysis result, where layers with spatial information from diverse origins have been used. A Cost-distance model is an efficient tool that gives good results in line with existing knowledge of species distribution (Nikolakaki 2004). In order to obtain a good model it is necessary to have a good knowledge of the species and the environment where they live, as it depends on the proper variable weighting (Adriaensen et al. 2003). Like other studies that use a similar methodology, the land use is the variable with greatest weight (Park & Lee 2003; Santos et al. 2004). The applied process is systematic, flexible and reproducible. Results of this study demonstrate the utility of GIS tools for providing specific habitat suitability models.

A considerable increase in wild boar populations (Arques et al. 2009), related to the increase of forest patches in the last decades (Peña 2007) emphasizing the environmental implications of recent changes on socio-economic processes at regional level. According to Farina and Belgrano (2004), the human modification of the landscape mosaic and all related ecosystem processes, generate ecological changes throughout the entire Mediterranean basin. The reduction of the health of the ecosystem has caused the recent and abrupt damages to the rural landscape, particularly in the European part of the Mediterranean. However, these conflicts can be resolved by reducing contacts between humans and

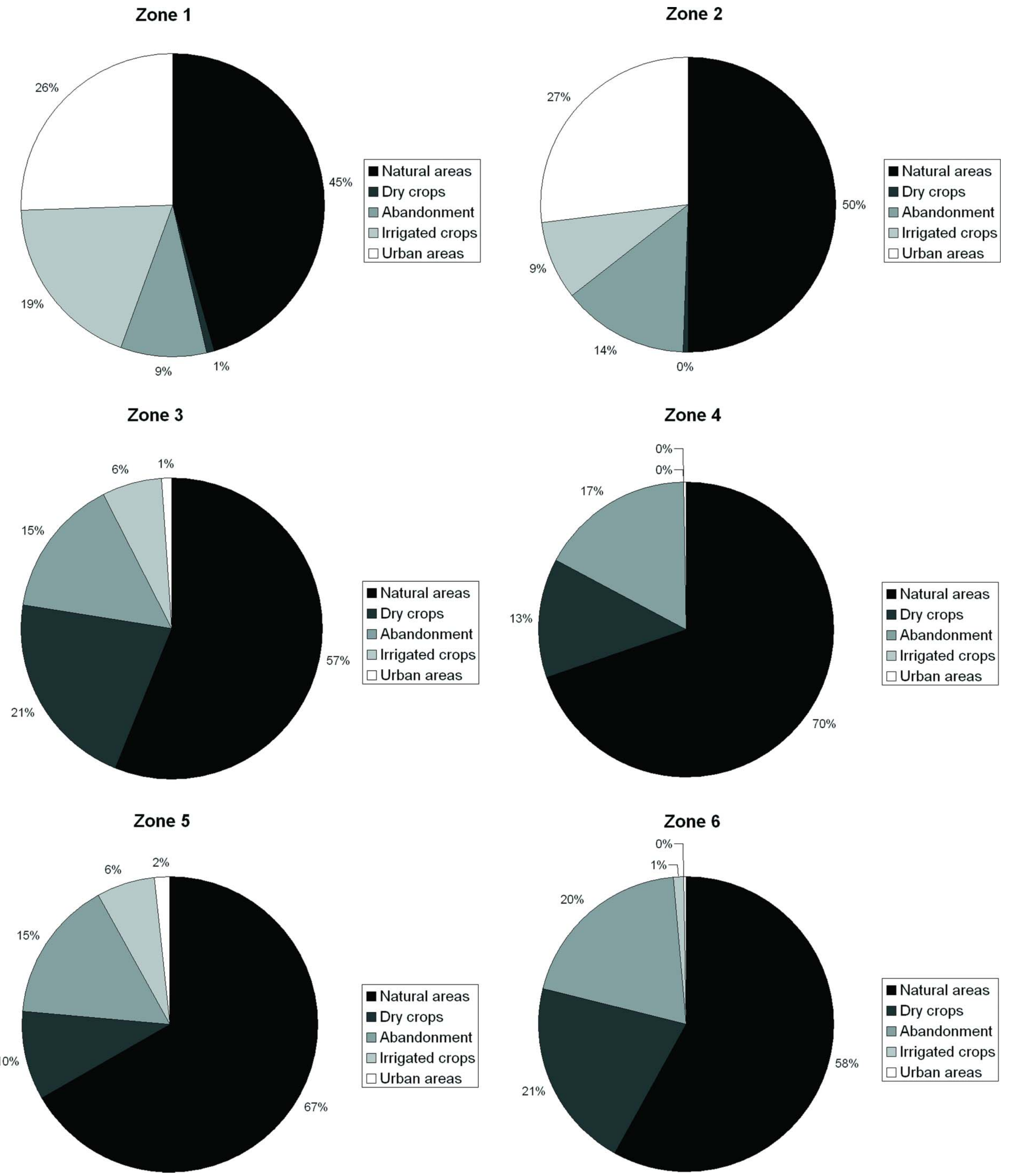

Figure 9. Diagrams of land uses in potential areas.

wildlife, and restoring and maintaining some natural areas to the fullest extent possible (Woodroffe et al. 2005).

A hierarchical conservation approach is recommended which, involving a wide range of scales and land use types, can help to detect the presence of ecologically important patches in the landscape matrix (Hostetler & Holling 2000). These patches may lose their ecological significance due to the wide home range of this species (Keuling et al. 2008b). Thus, the small natural fragments remaining after the urbanization process that, theoretically, have less ecological value when they are considered in isolation, it can complement the greater protected areas because they have the capacity to provide additional resources that will help to soften the edge effect, and increase habitat connectivity (Fischer & Lindenmayer 2002a; Parsons et al. 2003).

Efforts to preserve these small undeveloped patches within the urban matrix and close to large natural preserves may result in significant benefits at a regional scale, so these elements of landscape should not be dismissed when designing territorial management strategies (Marzluff & Ewing 2001; Fischer & Lindenmayer 2002a,b). We can conclude that the ecological limitations inherent to these small patches must be understood to ensure an adequate strategy of conservation related to present species (Hodgkison 2005). For this reason, it is necessary to analyze these landscape elements and assess their role in a transformed environment, which can act on the metapopulations presence, or in the dynamics of fragmented landscapes altered by human impact (Franklin 1993; Fischer & Lindenmayer 2002a).

In the potential areas, near the coast, there is a high cover value for the urban land use. This is due to the elevated number of small patches that correspond to urban sprawl of low density in the traditional agricultural and natural landscape matrix. Given the proliferation of tourist residential settlements a regional management plan is necessary to control this massive urban growth and to provide sustainable development. It is necessary to maintain the landscape connectivity with its surrounding area through the conservation of certain key structures that help the continuity of ecological processes in the landscape, making interconnected habitat networks by a combination of formally protected areas and other natural areas (Linehan et al. 1995; Forman & Collinge 1997).

The fauna, associated with small natural patches in the urban areas, can be affected by the nature and relationships between land uses and the landscape matrix (Gascon et al. 1999; Lindenmayer et al. 2002). The matrix can act as a selective filter, allowing the movement of certain species and acting as a barrier in the case of other species (Laurance 1997; Gascon et al. 1999).

Once optimal habitats are identified, greater knowledge about landscape connectivity for this species is available. This can help suitable management of such territories, especially when acting on the corridors that communicate potential areas of species distribution and these areas are within a transformed landscape. It is possible to influence the species mobility across the territory, through active management of this area. Thus, it is important to highlight the benefits of increasing the permeability of some infrastructures, such as AP-7 highway.

The present study shows the utility of a hunting species as an indicator of territorial dynamic, because the population reacts to episodes of change at a local scale. This method can also be applied to other game species in the region. Generalization of specific spatial requirements for habitat-selection depends on the spatial scale of analysis and on the selected species. The approach can be applied to each scale level depending on the selected species. The grid-cell size of raster maps must be selected according to home-range size of species. The flexibility of the GIS system enables precisely these changes (Nikolakaki 2004). In fact, this is a general approach that can be applied to every target species and it can be used as an interesting tool in territorial planning oriented to conservation and sustainable development.

Also, it would have been interesting to include data on the damage caused by the wild boar in the region. However, statistical data are not available due to a lack of resources. These statistics could be created from the data of complaints received by the security forces, but they are not computerized, and their access is severely restricted. Another future research line will try to create a GIS layer with the damages caused by the species in the region (traffic accidents or damage to crops, among others), to give a better solution to the problem. Ultimately, this research would contribute to sustainable land management, integrating the environment parameters and real needs of the species.

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