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SUSTAINABLE PLANNING OF LAND USE CHANGES IN FARMING AREAS UNDER ECOLOGICAL PROTECTION

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ABSTRACT Land use has been changing in the last decades because of agricultural intensification and land abandonment which implies deterioration in the optimum habitat structure and quality. Habitat degradation and loss, resulting from changes in land use remain significant drivers of biodiversity loss. These trends are widely recognised and have forced national and international agencies to identify protected sites for natural areas with high biodiversity value. Special Protection Areas (SPAs) are natural zones particularly relevant for nature conservation. Regional planning is bound to play an increasing role in nature conservation policies because much biodiversity is located in farming areas outside natural parks. Agriculture in the Mediterranean Basin has always been highly dependent on rainfed crops, cereal, vine and olive. Vine growing plays an important role not only from the economic point of view, but also environmentally as a permanent plant cover in terms of preventing erosion, managing land and water resources in a sustainable way, defending against desertification an settling population in rural areas. A Geographic Information System (GIS) was used to implement a decision tool system to analyse the feasibility of new proposals to upgrade traditional vineyards in Castilla-La Mancha, Spain. The study focuses on the sustainability of current farming practices in Special Protection Areas for Steppe Land Birds. This paper presents a model to quantify the resulting habitat fragmentation basing on infrastructure facilities, leading to mapping areas where to apply restriction measures to prevent physical destruction of the habitat.

Keywords: Land use planning, GIS, Viticulture, Habitat fragmentation

INTRODUCTION Human population has expanded rapidly, especially in the last two centuries, with associated expansion in industrialisation and urbanisation (Stanners and Bordeaux, 1995, Moran *et al*., 2004 and EEA, 2005). Land use has been changing in the last decades because of agricultural intensification and land abandonment (Tucker and Heath, 1994, Suarez *et al*., 1997) which implies a deterioration in the optimum habitat structure and quality for birds, showing a continued decline in recent decades (Santos and Suárez, 2005).

Agriculture in the Mediterranean Basin has always been highly dependent on the traditional trilogy of rainfed crops, which is cereal-vine-olive (Montero and Brasa, 2005). Vine growing plays an important role not only from the economic point of view, but also environmentally as a permanent plant cover in terms of preventing erosion, managing land and water resources in a sustainable way, defending against desertification an settling population in rural areas (Martín de Santa Olalla, 1994).

Habitat degradation and loss, resulting from changes in land use remain significant drivers of biodiversity loss (Hansen *et al*., 2004). These trends are widely recognised and have forced national and international agencies to identify protected sites for natural areas with high biodiversity value. The Habitats Directive (92/43/CEE) and the Birds Directive (Directive 79/409/CEE) are two of the most important European Union (EU) policy initiatives to conserve biodiversity across Europe.

Special Protection Areas (SPAs) are natural zones particularly relevant for the endangered bird conservation classified in accordance with Article 4 of the EC Birds Directive and included in a European Ecological Network (NATURA 2000). Regional planning is bound to play an increasing role in nature conservation policies because much biodiversity is located outside natural parks and other protected areas (Pino *et al*., 2000). There are 38 SPAs officially declared in the Region of Castilla-La Mancha, Spain, covering a total surface of 15776 km^2 (Dirección General del Medio Natural, 2007) which means almost 20% total region's surface. Six out of the 38 SPAs are steppe lands.

The ideal habitat for the steppe land birds is a landscape mosaic consisting on extensive rainfed cereals, some fallow plots, rainfed leguminous and natural meadows (Palacín *et al*., 2004; Martínez, 1994) The distribution pattern is very fragmented, surviving in areas of habitat which are more or less reduced to islands isolated in a matrix of highly modified habitats affected by new irrigation plans, shrublands colonisation alter land abandonment, new large infrastructures and vineyard modernisation (García *et al*., 2007). Steppe land birds avoid in general being near to inhabited places or highly transited roads (Alonso & Alonso, 1990; Lane *et al*., 2001).

The great bustard (*Otis tarda*) is worldwide endangered (BirdLife International, 2000) as a consequence of the expansion and growing of human population. Over 50% of the world's population of the globally threatened great bustard is concentrated in the Iberian Peninsula (Pinto *et al*., 2005). The current Spanish population is estimated around 22.429 individuals and 4.775 in Castilla-La Mancha (Alonso *et al*., 2005).

There is a total vineyard area of 528.931 ha and 5.2% (27.628 ha) are located in the steppe SPAs. The traditional vineyard growing system is, on itself, an inappropriate habitat for the great bustard, although some authors believe that it is used as refuge or as food source (Palacín *et al*., 2004).

Bird population's survival may depend on a dynamic balance between local population, extinctions and colonisations (Opdam, 1987). Connectivity is also a factor depending on the interconnection between ecological elements of the landscape which allow species to move amongst them (Jaarsma & Willems, 2002). Tracks and roads create barriers which cause landscape and population fragmentation because these elements are normally the limits (Ena *et al*., 1985).

On the other hand, five designations of origin (DO) of vineyard are affected by SPA: Méntrida, Mancha, Valdepeñas, Almansa y Jumilla. Therefore it can be foreseen that these vineyard areas would be affected by the use restrictions established by the SPA management plans, because many farmers have applied for reforming their old vineyards into irrigated vineyard trellis.

Landscape planning is essential to manage land use conflicts and ensure the sustainability of ecological, economic and social systems in a region. This decision-making needs to be supported by accurate and detailed information about the spatial distribution of a raft of parameters affecting the distribution of land use (Bryan, 2003). Landscape visualization techniques enable the qualitative interpretation of landscapes and can be powerful decision support tools in landscape planning. GIS provide easy and consistent access to natural resource data and thus should be considered as very useful tools to integrate information coming from different sources, which makes it very efficient for viticulture land-use planning and management (Lang, 1996; Montero and Brasa, 2004).

Solutions to most landscape-scale problems require access to comprehensive spatial databases describing natural, cultural and economic resources, that are often unavailable or of questionable reliability. Coupling of GIS with process and assessment models and graphical user interfaces results in a variety of decision support tools which integrate and organize information necessary to make timely and informed decisions with consistent recommendations based on document decision criteria (Johannsen *et al*., 2000).

This paper describes results achieved in a research project to provide guidelines for the agricultural use of land within SPA, focussing on land-use management concepts from the viewpoint of vine growers, conservationists and decision makers by using GIS tools.

MATERIALS AND METHODS

Study area This work covers the Special Protection Areas (SPA) for steppe land birds of Castilla-La Mancha, Spain. Table 1 shows area figures of the SPAs.

Table 1. Vineyard area in SPA for steppe land birds of Castilla-La Mancha, Spain.

SPA	Vineyard area		Overall area
	(ha)	(%)	(ha)
North La Mancha	21383	19.9	107248
East Albacete	3457	13.4	25760
Campo de Montiel	2090	13.0	16110
Guadarrama	562	4.42	12719
El Bonillo	136	0.79	17280
La Campiña	0	0	2496
Total	27628	15.2	181613

GIS design The Geographic Information System (GIS) was built over a Workstation with double processor Intel® Xeon® 5120 at 1.86 GHz and 8.00 GB of RAM memory; graphics card NVIDIA Quadro FX 3500 with a twin output, and operative system Windows® XP® Professional x64 with SP2. The information was treated using ArcView® 3.2 and ArcGIS® 9.3, from ESRI® (Redlands, Californifa, USA); ArcPad was used as platform for mobile devices (PDA).

Preliminary geographic information was achieved from the NGI (National Geographic Institute), the Ministry of Agriculture, Fisheries and Food GIS aerial photographs, as well as the new images from the National Aerial Ortophotography Plan (PNOA) available through a WMS server. Cadastre and Castilla-La Mancha vineyard field registry were used for vine-growing data assessment of the involved places. To avoid incompatibility when using different information layers, the same coordinates system UTM Datum ETRS89, Zone 30 N was always used.

Great Bustard sighting The Environmental Agency of Castilla-La Mancha (2008) provided the Great Bustard sighting data, considering possible sighting areas those which are within less than 1 km far from the sighting point; and strips between 1 and 1.5 km and between 1.5 and 2 km, corresponding to areas likely used for this species (Figure 2).

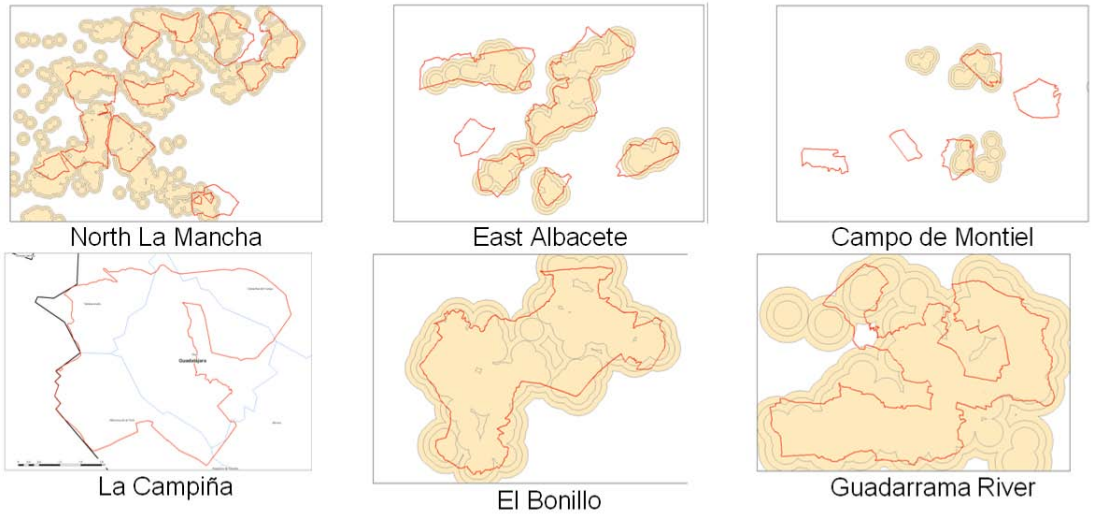

Figure 2. Great Bustard sighting (source: Natural Sites Autonomous Organization, 2008).

Land use description Within the SPAs for steppe land birds there is a vineyard surface of 27.628 ha, that is, 5.2% of the total Castilla-La Mancha's vineyard surface, but represents 15.2% of the total 6 SPA's surface.

The Great Bustard is very sensitive to all kind of habitat changes, so avoiding any alteration of the current land distribution and its uses was a primary hypothesis to be considered; the abandonment of traditional farming in favour of new intensive systems and the simplification of the steppe landscape, results in habitat losses, fragmentation or worsening (Alonso *et al.*, 2003). The traditional vineyard transformations into more intensive farming models "vineyard trellis" entail new devices and structures that might be uncomfortable and move around the Great Bustard habitat.

With the GIS, the distribution of different land uses in each special protection area is analysed. Vineyard areas were marked out and groups of contiguous plots were called "block"; its average size and the minimum distance between them was determined.

Figure 3 shows the heterogeneity of the vineyard distribution in each special protection area. In the steppe land of "North La Mancha", the vineyards fields reach 20% surface occupation with quite define blocks; in the steppe land of "East Albacete", the vineyards

fields are very spread but with well define blocks; the steppe lands of "Campo de Montiel" showed big differences among the different blocks; in the cereal steppe lands of "La Campiña" there weren't any vineyards; in the steppe land of "El Bonillo" the vineyards are rare and spread; in the right bank of the Guadarrama river, the vineyards presence is very irregular but specifically located in big plots under intensive framing systems; in the cereal steppe land of "La Campiña" there isn't any vineyard plot, so this special protection area was dismissed for further analysis.

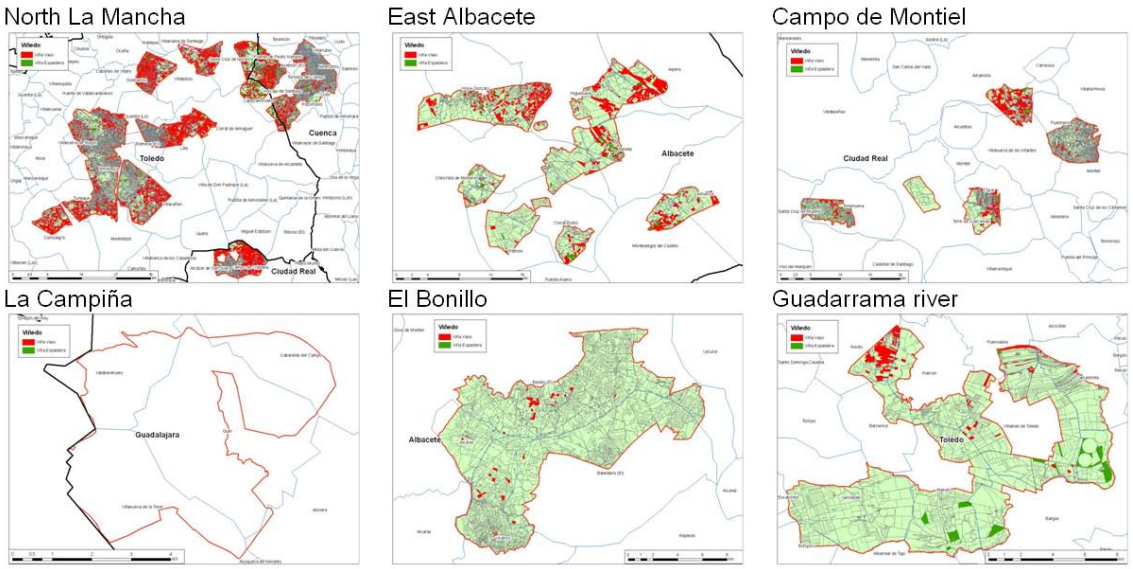

Figure 3. Vineyard fields distribution (in red) within the 6 special protection areas for steppe land birds in Castilla-La Mancha, Spain

Spatial analysis of vineyard continuity in the Special Protection Areas To analyse the land continuity of vineyards within the special protection areas an analysis procedure described by Thiessen (1911) and based on spatial uniformity was applied. The method consisted in making polygons around the sighting points to define their influence area. The blocks were taken, determining their gravity centre. Thiessen polygons, also Voronoi polygons or Thiesselation of Dirichlet, is the easiest interpolation method based on the Euclidean distance.

This is one of the basic analysis functions of the GIS. Each Thiessen polygon represents a virtual area for each vineyard block, so that i) each polygon only contains one vineyard block, ii) all the special protection area surface is contained in one of the polygons iii) whatever location inside the polygon is closer to its centre than to any other place. Small Thiessen polygons mean closer vineyard blocks, thus showing higher level of vineyard continuity; big Thiessen polygons represent more isolated vineyard blocks.

Aptitude analysis of areas for steppe land birds The Great Bustard lives in big areas without interferences (Peris *et al*., 1991) and avoids the proximity to inhabited places and busy tracks (Lane *et al*., 2001) Therefore, big areas free of artificial elements like urban centres, spread buildings, communication tracks, etc. were defined.

The Environmental Agency of Castilla-La Mancha (2008) defines an influence area of 200 m for each element or artificial infrastructure as non suitable for steppe birds' habitat.

Those areas free of barrier elements are called “Open zone”. These areas are obtained by withdrawing all the artificial elements or infrastructure as well as their corresponding influence areas from the total Special Protection Area for steppe land birds’ surface. Calculating these influence areas (Buffer) is a basic function in GIS (Peña, 2006).

Also, The Environmental Agency of Castilla-La Mancha (2008) estimates that Great Bustards need an area of at least 25 ha free of artificial elements or infrastructures to live, thus, from the “open zones” obtained, only those greater than 25 ha were selected. The biggest barrier density is found nearby urban centres as well as in intensive framing areas, so according the steppe land birds’ necessities, these areas can be considered non suitable to settle and they will try to find wider areas less crowded

RESULTS AND DISCUSSION

Vineyard continuity in the Special Protection Areas Once Thiessen’s polygon method was applied, each SPA’s area is divided into irregular polygons which surface depend on the vineyard continuity, therefore a normalization based on quantitative classification by surface in four levels (high, medium, low, null) is applied to each SPA (Figure 4).

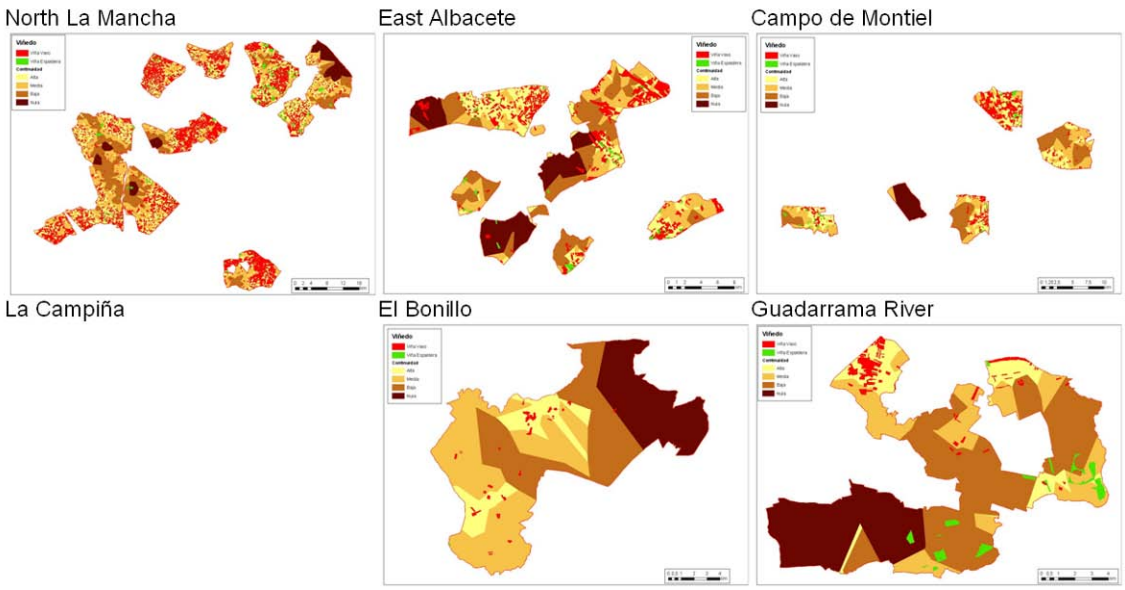

Figure 4. Spatial continuity of vineyards within SPA for steppe land birds

Table 2. Suitable and non suitable areas for Great Bustard settles

SPA	Overall Area (ha)	I* area (ha)	I* +buffer (ha)	Unsuitable Area		Suitable Area	
				ha	%	ha	%
North La Mancha	107248	1768	24535	27337	25	79909	75
East Albacete	25759	475	5077	4976	19	20780	81
El Bonillo	17280	288	3687	3996	23	13284	77
Campo de Montiel	16110	281	3600	3761	23	12349	77
Guadarrama River	12719	266	2471	2324	18	10395	82

* I: Man-made Elements and Infrastructures

Land aptitude for steppe birds The distribution of suitable and non suitable areas for each SPA is shown in Table 2. It is pointed out that among different SPAs there is a range between 18% and 25% of the surface which is not suitable for the Great Bustard either for being to close to artificial elements or infrastructures, or for being small areas surrounded by those elements.

Intensive vine-growing uses compatibility From the results of the previous analysis described in the methodology, and considering available for intensive vineyard growing areas with high and medium vineyard continuity combined with non suitable areas for the Great Bustard, and considering not available for intensive vineyard growing areas with low or null vineyard continuity combined with suitable areas for the Great Bustard, it can be concluded that 64% total SPAs area is unfeasible for transformation (Table 3).

Table 3. Feasible and non feasible surfaces for vine-growing uses compatibility summary

SPA	Overall Area (ha)	Unfeasible Area		Feasible Area	
		ha	%	ha	%
North La Mancha	107248	62009	58	45237	42
East Albacete	25759	18676	27	7081	73
El Bonillo	17280	12181	70	5099	30
Campo de Montiel	16110	8752	54	7358	46
Guadarrama River	12719	11322	89	1398	11
La Campiña	2497	2497	100	0	0
Total	181613	115437	64	66173	36

Figure 6 shows the current vineyard surface superimposed over the result of the study to confirm that the majority of the current vineyards are placed in feasible areas.

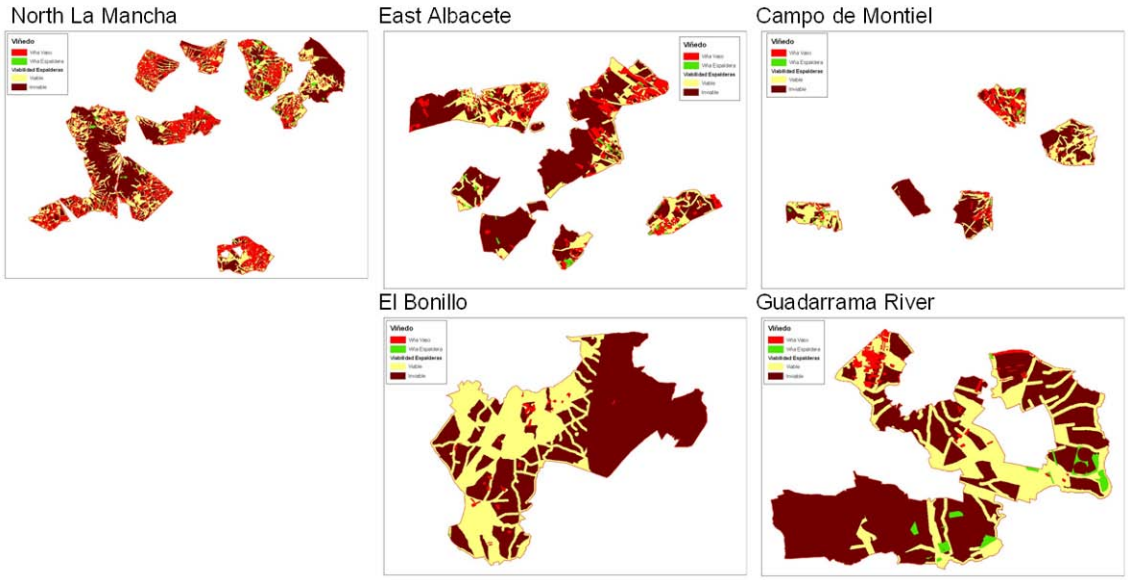

Figure 6. Vineyard (red) overlapping feasible (yellow) and unfeasible (dark brown) areas for transformation or new intensive vineyard plantations in SPA for steppe land birds.

CONCLUSSIONS It is not advisable to alter the current land uses distribution within every special protection areas (SPA); therefore the new vineyard trellis should be located where old vineyards fields are presently located. Consequently, keeping the same overall vineyard area in every SPA would be appropriate.

To avoid changing the current vineyard distribution in each SPA, new plots could be established according to different rights assignment within the same SPA, taking into account the unfeasible areas and applying a surface reduction in the replanted areas between 5 and 20% of the previous plot. In these areas there would not be any further limits to authorize vineyard trellis, and thus it would not be necessary to introduce further agronomic restrictions. To enhance the steppe land birds' habitat it is proposed to dedicate the pulled up vineyard surfaces to extensive dry land cereal growing.

A minimum distance between plots is proposed to be longer than the average distance within SPA:

- North La Mancha: 499 m
- East Albacete: 670 m
- Campo de Montiel: 506 m
- Guadarrama River: 1195 m

Likewise, the establishment of plantation blocks should be in a way that these blocks should not be bigger than the average size within each SPA:

- North La Mancha: 1,4 ha
- East Albacete: 1,7 ha
- Campo de Montiel: 1,8 ha
- Guadarrama River: 3,4 ha
- Bonillo: 1,5 ha

Specific agronomic conditions are suggested to be applicable for new plantation proposals inside a SPA, and for those plantations coming as a result of an intra-SPA different rights assignment. To avoid territory fragmentation and barrier effect, the maximum line length should be reduced and the plantation frame wide enough to allow the birds to move freely without any physical hazard.

There are signs that indicate a negative selection toward vineyard trellis from the steppe land birds, particularly the Great Bustard, so an increase of this type of vineyard growing could lead to a fragmentation of the available SPA for steppe land birds' habitat. However, according to the obtained results in this work, a series of different measures should be taken to promote compatible activities with nature conservation and restrict those that either for its intensity or its execution are incompatible.

In the same way, relating to sensible zones planning management, the Law of Nature Conservation of Castilla-La Mancha estates that sensible areas must include a management plan in which compulsory conservation measurements would be defined according to the ecologic demands of the natural resources for which these plans have been created.

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