Chapter

LAND-USE CHANGES AND BIODIVERSITY CONSERVATION IN AGRICULTURAL LANDSCAPES. A CASE STUDY

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ABSTRACT

A wide range of global biodiversity is concentrated in rural landscapes. Indeed, many wild species and natural habitats are directly or indirectly associated with agricultural systems. In turn, some genomes of wild species can contribute, on one hand, to agricultural productivity and quality and, on the other, to ongoing biological control of crop-specific pests. Thus, management of these landscapes should consider applying

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agricultural practices adapted to biodiversity conservation, which will also result in enhanced production levels.

One way to infer the state of conservation of biodiversity in rural landscapes is through knowledge of their spatial structure, i.e., the configuration and composition of different land uses and remnant natural vegetation. This knowledge can serve to evaluate the behavior of the ecological processes associated with the above mentioned structure and to assess the integrity of the landscape and its potential biodiversity. The current spatial pattern of the landscape is the result of changes in land uses and management practices therein throughout time, essentially as a result of socioeconomic changes. Study of these changes enables us to propose future scenarios based upon the design and implementation of management policies that consider the history of the aforementioned changes.

Moreover, it is interesting to note the growing interest of agricultural policies, at different levels (for example, the Common Agriculture Policy at European level), in ecological compensation measures for agricultural areas (specific subsidies) involving conservation and improvement of biodiversity. The receiving of certain subsidies depends on the correct application of feasible agro-environmental models. In this sense, spatial analysis of the landscape and changes therein can be useful for more effective conservation of biodiversity while maintaining an optimum level of productivity, which can be seen in the diverse models applied in different regions.

The present study, conducted in Andalusia in southern Spain, consisted of analysing the spatial structure of a rural landscape of olive groves, as well as the dynamics of change in land uses and land cover over a period of 50 years. The study results show a trend towards intensification of olive cultivation (mainly irrigation and increased energy inputs), a greater area occupied by these crops and maintenance of the area covered by natural vegetation and even an increase therein. As a result of these processes, the landscape has maintained an acceptable level of connectivity, diversity of land uses and spatial heterogeneity. This situation enabled us to infer a good situation for biodiversity conservation and for the potential restoration of the rural landscape studied. Our results highlight the need for an agro-environmental model at landscape-scale for the conservation of biodiversity and maintenance of a reasonable level of profitable productivity. We therefore recommend the abandonment of less productive farmland and a spatial landscape configuration based upon the 'land sparing' alternative. This alternative involves the persistence of remnants of useful native vegetation such as: natural or semi-natural habitats (essential for species specialised in agricultural systems); discontinuous corridors (stepping stones) and the potential restoration of native vegetation.

INTRODUCTION

The relationships existing between land use and biodiversity are fundamental with regard to understanding the links between people and their environment (Haines-Young 2009). Throughout history, land-use activities have transformed much of the world's terrestrial ecosystems. Human land-uses generally involve acquiring natural resources for immediate needs, often at the expense of degrading environmental conditions (Foley et al. 2005). In much of the planet, land-use changes constitute the most important driver of transformations in biodiversity and ecosystem services. Some direct consequences of these changes are, among others, habitat change, invasive exotic species, and overexploitation.

Many authors, e.g. Chapin et al. (2000) and Sala et al. (2000), highlight the fact that by 2100, the impact of changes in land uses on biodiversity will likely be the most significant driver of biodiversity change at global scale. Ultimately, changes in land uses and management are key drivers of changes in biodiversity, not only at global but also at national and local scale (Haines-Young 2009).

In some situations, however, human land-uses have conserved, or even promoted an increase in, biodiversity. Numerous examples of this can be in traditional rural landscapes such as *dehesas* and *montados* (open savannah-like woodlands used as pastures) or extensive livestock farming in mountains (Plieninger and Wilbrand 2001; Rescia et al. 2010). Indeed, much global biodiversity is concentrated in rural landscapes and one can even find wild species and natural habitats directly or indirectly associated with these landscapes.

A vital aspect of rural landscapes involves their agricultural production, which can also be linked to biodiversity. In this sense, some genomes of wild species can contribute, on one hand, to agricultural productivity and quality and, on the other, to maintaining biological control of crop-specific pests. Thus, management of rural landscapes should consider applying agricultural practices adapted to the conservation of biodiversity which, in turn, will result in enhanced production levels.

Moreover, it is worth noting the growing interest of agricultural policies, at different levels (for example, the Common Agriculture Policy at European level), in ecological compensation measures for agricultural areas (that is, specific subsidies) involving conservation and improvement of biodiversity. The receiving of certain subsidies depends on the correct application of feasible agro-environmental models.

In this sense, spatial analysis of landscape and changes therein can be a useful tool to ensure more effective biodiversity conservation while maintaining an optimum level of productivity, which can be seen in the diverse models of management, applied in different rural landscapes. One way to infer the state of conservation of biodiversity in rural landscapes is through knowledge of their spatial structure, i.e., the configuration and composition of different land uses and remnant native vegetation. This knowledge can be used to evaluate the behavior of ecological processes associated with this structure and therefore to assess the integrity (functionality) of the landscape and its potential biodiversity.

Essentially, landscape transformations are due to socioeconomic changes and current spatial pattern of the landscape results from changes in land uses and management practices along time. Study of these changes enables us to propose possible future situations based on the design and implementation of management policies that consider the history of changes occurred. In some cases, for achieve a viable agri-environment scheme there is a vital need to control landscape structure and changes therein. This situation is particularly evident in rural landscapes characterised by an agricultural system focusing upon intense production of one single food product.

An example of this type of agricultural landscape involves woody crops such as olive groves, which can be found throughout the Mediterranean Basin. In Spain, olives trees (*Olea europaea* L.) have for centuries been cultivated for olives and olive oil. Historically, this woody crop has been exploited extensively in rain fed regimes even on sloping land (Duarte et al. 2008; Stroosnijder et al. 2008) constituting a type of landscape of great cultural, social, economic and traditional value. However, in relatively recent times, more intensive management practices are being implemented (Sánchez-Martínez et al. 2011).

The intensification in agricultural practices and land use changes at local scale has led to a landscape transformation at global scale. These changes in land uses and land management are having serious consequences for structural and functional landscape characteristics and for biological parameters such as biodiversity in different regions. It is therefore highly important to study different cases about these consequences of land use changes. With this in mind, in our study we analysed changes in land-uses during the last 50 years, as well as the present landscape structure in an agricultural landscape characterised by the exploitation of olive groves. This analysis served to propose the best spatial landscape planning for optimizing production with the lowest possible cost to the environment (i.e., conserving biodiversity).

STUDY AREA

The classification Protected Designation of Origin (PDO) of *Sierra de Segura* extra virgin olive oil is applied to a territory in the Andalusia region, in southern Spain (Figure 1). The PDO is the system used in Spain for the recognition of quality food products protected by European Union (EU) legislation. The study area, the *Sierra de Segura* PDO, occupies an area of approximately 200,000 ha and olive trees occupy approximately 20% of the PDO area. The olive groves are principally located in the mountain range of *Sierra de Segura*, much of this area falling within the "*Sierras de Cazorla, Segura and Las Villas*" Natural Park. This Nature Reserve contains Spain's biggest continuous pine forests, the European Black pine (*Pinus nigra*) being the most conspicuous native species in the Reserve. There are also some deciduous forests as well as more typically Mediterranean sclerophyllous vegetation, along with *dehesas* in the lower areas.

The topography of *Sierra de Segura* is very mountainous and the predominant climate in the area is Continental Mediterranean with a Subtropical Mediterranean influence.

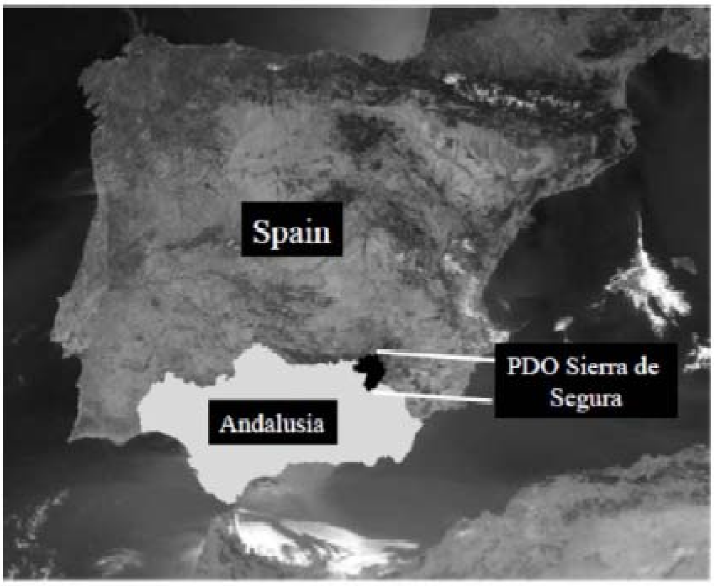


Figure 1. Location of the study area, Protected Designation of Origin (PDO) of *Sierra de Segura* extra virgin olive oil, in the Andalusia region, southern Spain.

LAND USES CHANGES AND LANDSCAPE TRANSFORMATION IN *SIERRA DE SEGURA* (PROTECTED DESIGNATION OF ORIGIN AND NATURE RESERVE)

We analysed the landscape change over the last 50 years, as well as the current spatial structure of landscape of *Sierra de Segura* using landscape metrics (O'Neill et al. 1988; Rescia et al. 1994, 2010). These were applied on land-use and land-cover types maps of the study area (Figure 2).

These maps were generated with data information from the Andalusia Regional Government and the land-use and land-cover types used were adapted from LCUISS classification (Land Cover and Use Information System of Spain), developed by Andalusia Environmental Department (SIOSE, 2005). Two time windows were considered: 1956 and 2007.

We also used transition matrices (Pontius et al., 2004) to characterise the type of change with the land-use maps and land-cover types of the study area and for the same time windows. Finally, we have proposed a landscape spatial design in the context of a multifunctional agri-environment scheme based upon agricultural production and biodiversity conservation.

Table 1 shows the evolution of the area and relative presence of the different land uses considered during the last 50 years. The study area showed an increase in the spatial occupation of the rain-fed olive groves (4%, almost 8,000 ha more) but this was accompanied by a relevant decrease in the area of rain-fed herbaceous crops (a 6% decrease involving 12,000 ha). With regard to land management, there were signs of intensification along with abandonment in the olive groves (700 ha under irrigation recently implanted and 200 ha abandoned). Furthermore, there was a slight increase in natural vegetation (more than 5% between conifers and other tree formations) and a marked expansion in *dehesa* cover (scrub and grasslands with trees) with different degrees of human pressure.

In short, the area occupied by crops has shown a slight decrease (from 32% to 28%) accompanied by an increase in natural vegetation and extensive traditional uses (from 65% to 68%, Figure 3). The *Sierra de Segura* PDO is a heterogeneous rural landscape comprising a high percentage of natural vegetation, increasingly more rain-fed olive groves and an incipient expansion of irrigated olive groves. In Table 2 metrics calculated for some of the land uses selected (due to their representativeness or to their ecological or production interest) show the variation of different aspects of these land uses over time. At the local scale (patch scale), the spatial structure of agricultural patches (representing the production aspect of this heterogeneous landscape) has varied in two different senses. On one hand, the number of patches of rain-fed olive groves has shown an increase while the spatial pattern (distance among patches and spatial distribution, ENN MN and IJI indices, respectively) has remained stable.

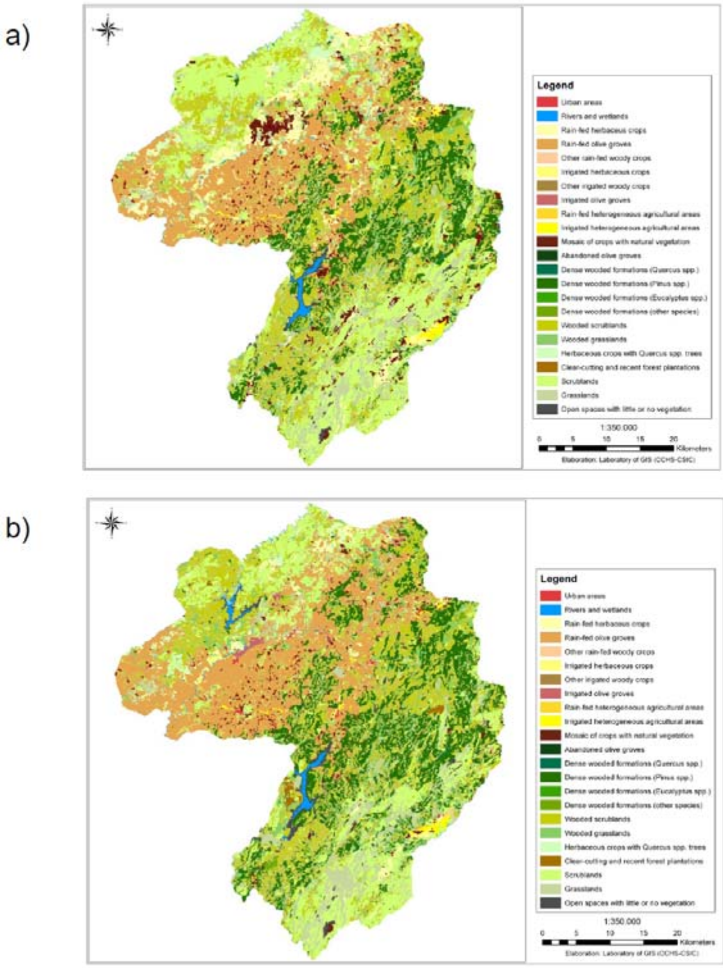
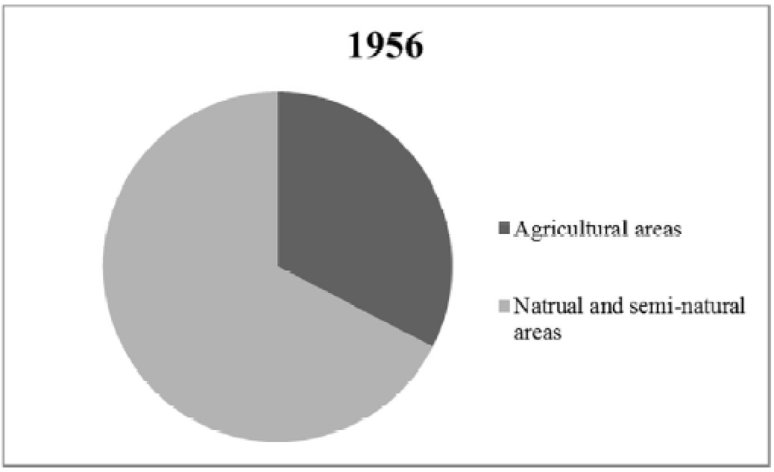


Figure 2. Land uses and land covers identified in the PDO of *Sierra de Segura*, corresponding to years a) 1956 and b) 2007.

Table 1. Temporal evolution of the land uses and land covers identified in PDO *Sierra de Segura* from 1956 to 2007. CA (Class Area) represents the total area occupied by each land use/cover. PLAND (Percentage of Landscape) the proportion of the landscape occupied by each land use/cover

Land uses/land covers	1956		2007	
	CA (ha)	PLAND (%)	CA (ha)	PLAND (%)
Urban areas	468	0.22	1,115	0.51
Rivers and wetlands	5179	2.39	5,369	2.48
Rain-fed herbaceous crops	18,083	8.34	5,676	2.62
Rain-fed olive groves	39,181	18.07	46,696	21.54
Other rain-fed woody crops	19	0.01	130	0.06
Irrigated herbaceous crops	629	0.29	601	0.28
Other irrigated woody crops	-	-	5	0.00
Irrigated olive groves	-	-	705	0.33
Rain-fed heterogeneous agricultural areas	552	0.25	262	0.12
Irrigated heterogeneous agricultural areas	798	0.37	739	0.34
Mosaic of crops with natural vegetation	7,500	3.46	2,806	1.29
Abandoned olive groves	-	-	205	0.09
Dense wooded formations (*Quercus spp.*)	205	0.09	231	0.11
Dense wooded formations (*Pinus spp.)*	30,897	14.25	40,994	18.91
Dense wooded formations (*Eucalyptus spp.*)	3	0.00	8	0.00
Dense wooded formations (other species)	149	0.07	601	0.28
Wooded scrubland	50,625	23.35	54,242	25.02
Wooded grasslands	5967	2.75	8,055	3.72
Herbaceous crops with *Quercus spp.* trees	1,595	0.74	1,369	0.63
Clear-cutting and recent forest plantations	238	0.11	787	0.36
Scrubland	40,842	18.84	30,731	14.18
Grasslands	12,952	5.97	13,554	6.25
Open spaces with little or no vegetation	911	0.42	1,910	0.88



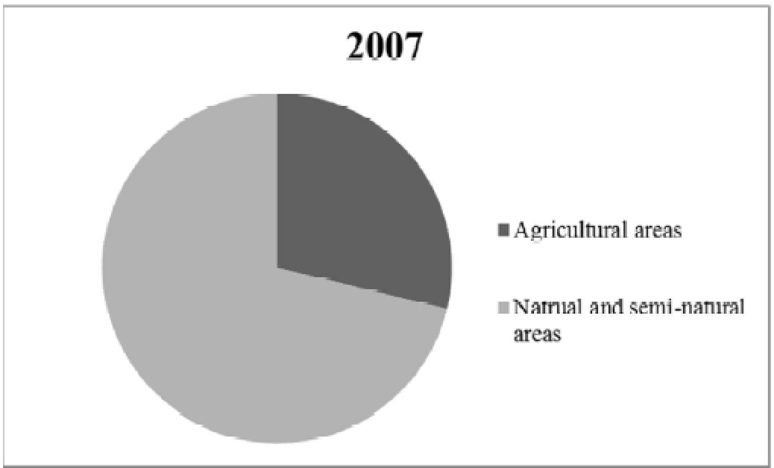


Figure 3. Proportion of the agricultural area (included all type of crops and crops mixed with natural vegetation) and natural and semi-natural vegetation area in the PDO of *Sierra de Segura* for the two years considered.

On the other, there has been a great loss of rain-fed herbaceous crops (approximately half of the patches of this land use) which in turn has increased the distance between the patches but with more compact distribution thereof (low IJI). With regard to the spatial structure of land-cover patches (natural vegetation patches), essentially all these have increased in number. The patches of pine, in particular, have occupied a bigger area with no change in their spatial pattern, that is, the pine formations were isolated both in 1956 and 2007 (low IJI). As a result of the changes of land-use patches, there has been a fragmentation process (higher NP and PD and lower AREA MN) at the landscape scale, and, at the same time, in these decades the landscape of *Segura* has shown an increase in its degree of connectivity (it has a high PROX index and low ENN and IJI indices).

Table 2. Variation of land use and land cover patches indices from 1956 to 2007. NP: number of patches; AREA_MN: mean area of all patches; ENN_MN: mean Euclidean nearest neighbour distance; IJI: interspersion and juxtaposition index, measures the extent to which patch types are interspersed (for more details see McGarigal 1995)

Land uses/land covers	1956				2007			
	NP	AREA_MN (ha)	ENN_MN (m)	IJI (%)	NP	AREA_MN (ha)	ENN_MN (m)	IJI (%)
Rain-fed herbaceous crops	1,369	13.21	172.00	72.96	680	8.35	251.20	67.71
Rain-fed olive groves	1,063	36.86	117.90	71.90	1,301	35.89	102.22	70.06
Irrigated herbaceous crops	123	5.11	678.27	68.64	100	6.01	608.79	64.25
Irrigated heterogeneous agricultural areas	42	19.00	297.94	68.40	48	15.41	433.84	68.87
Mosaic of crops with natural vegetation	1,032	7.27	256.29	69.52	854	3.29	286.01	59.42
Abandoned olive groves	-	-	-	-	100	2.05	1,118.09	43.54
Dense wooded formations (*Pinus spp.)*	849	36.39	156.45	54.89	1,465	27.98	121.41	48.93
Wooded scrubland	2,540	19.93	102.63	63.40	3,636	14.92	89.02	58.95
Wooded grasslands	1076	5.55	274.88	59.54	1,385	5.82	235.89	56.25
Scrubland	1,949	20.96	166.70	64.43	2,167	14.18	167.00	60.40
Grasslands	2,026	6.39	208.54	63.14	1,912	7.09	190.61	60.91

Table 3. Variation in landscape indices from 1956 to 2007. NP: number of patches; PD: patch density; AREA_MN: mean area of all patches; PROX_MN: mean proximity distance size of all patches; ENN_MN: mean Euclidean nearest neighbour distance; IJI: interspersion and juxtaposition index, measures the extent to which patch types are interspersed; PR: patch number; SHDI: Shannon diversity index; SHEI: Shannon evenness index; HL: heterogeneity of landscape; CS: spatial complexity (for more details see McGarigal 1995; Rescia et al. 2010)

Landscape indices (units)	Years	
	1956	2007
NP (unitless)	14,432	16,655
PD (Nº/100ha)	6.66	7.68
AREA_MN (ha)	15.02	13.02
PROX_MN (unitless)	1,758.93	2,459.45
ENN_MN (m)	200.30	192.15
IJI (%)	65.83	60.58
PR (unitless)	20	23
SHDI (unitless)	2.07	2.03
SHEI (unitless)	0.69	0.65
HL (bit)	0.15	0.14
CS (bit)	0.31	0.29

While some new land-use types have appeared (PR from 20 to 23), the values for diversity, evenness, heterogeneity and complexity indices have remained relatively stable, albeit with a slight increase (Table 3).

The typology of the main changes in the time period studied can be seen in Figure 4. This Figure shows that the most notable change involves the transformation from herbaceous crops to olive crops (7,100 ha from 1956 to 2007) and the abandonment of these crops (3,000 ha between 1956 and 2007, transformed to grasslands or scrubland). As for the natural vegetation, different changes have taken place, but the general trend has involved 'lignification' of the landscape. That is to say, scrublands and grasslands have given way to wooded formations and *dehesas*, and there has been an increase in the area occupied by conifers.

The increase in the area of olive groves has had little effect upon the natural vegetation, tending to concentrate its expansion along an EW strip; Northern of the PDO, with an incipient progress to the South. In general terms, almost 65,000 ha of the PDO has changed in the last 50 years.

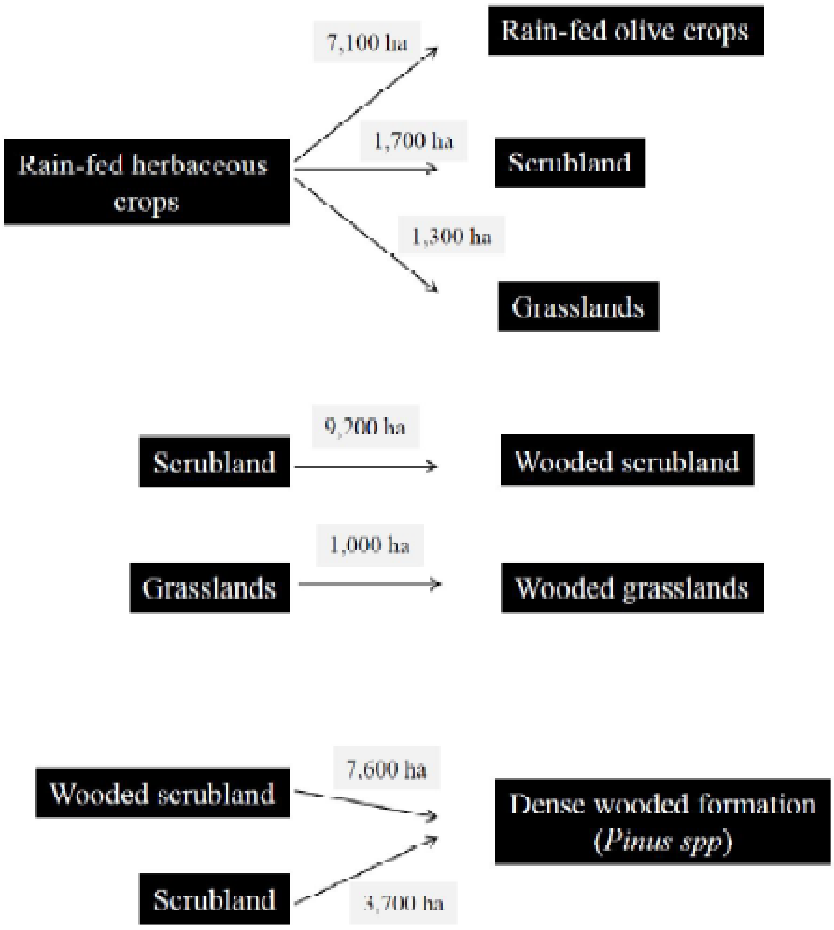


Figure 4. Typology of the land use and land cover changes for the time period studied in the PDO of *Sierra de Segura*. Data are based on transition matrices (1956-1999; 1999-2003; 2003-2007).

AGRICULTURAL PRODUCTION AND BIODIVERSITY CONSERVATION IN THE CURRENT MULTIFUNCTIONAL LANDSCAPE OF *SIERRA DE SEGURA* PDO

The evolution of the *Sierra de Segura* landscape should be analyzed from the perspective of the restrictions inherent to a protected area, considering that

90% of the study area falls within a Nature Reserve. In this context, the evolution of changes in land uses in *Segura* can be considered to be relatively balanced from environmental and production point of view. In other words, the landscape has shown an increase in agricultural land, mainly olive groves, while maintaining (or even increasing) the area covered by natural vegetation. In particular, wooded land and trees on scrub and grasslands have shown an increase in area. However, unlike other rural landscapes (Rescia et al. 2010), the spread of olive groves in the *Sierra de Segura* has occurred on soils that had already been used for agriculture. Consequently, management measures adopted for the future evolution of the study area should focus on controlling the tendency to spread of olive crops (which is expected to continue in the coming years, see Loumou and Giourga 2003; Camarsa et al. 2010) for not occurring on soils unsuitable for agriculture (high slope, for example) or occupied by natural vegetation.

Despite the negligible changes in land uses and land covers, they have had some impact on the spatial structure of the landscape. Specifically, the spatial configuration of the landscape of *Segura* has shown an increase (or has maintained) in connectivity, diversity, heterogeneity and complexity, features which contribute to increasing the functionality of the landscape and to maintaining the flow of services provided by this rural landscape. Concurrently, these small changes in the spatial configuration of the landscape have also had an impact on agricultural production in the PDO and its agro-biodiversity and potential biodiversity. On one hand, the bigger area occupied by the olive groves has led to higher production of olive oil. On the other, in relation to biodiversity (not measured in this study) one can make some inferences from other studies relating this parameter with the spatial structure of the landscape (Rescia et al. 1994, Fahrig 2003).

In the case of *Segura*, the conditions for maintaining a high degree of potential biodiversity are optimal. This is a rural landscape in which crops (mainly olive trees) constitute one component within a highly heterogeneous landscape. Indeed, the area occupied by natural or semi-natural vegetation (such as *dehesas*) is even higher than the area occupied by croplands and the degree of connectivity of patches as well as their average size have increased over the last 50 years. Thus, in this type of heterogeneous rural landscapes, the best management option for achieving reasonable values of agricultural production and for biodiversity conservation involve the application of localized intensive agriculture (on croplands) while retaining relatively large remnants of natural or semi-natural vegetation. In these circumstances, these remnants would act both as habitats (vital to native species and species adapted to farming systems) and as stepping stones or as potential reservoirs for the restoration of natural vegetation (Nekhay et al. 2009; Letourneau et al. 2011).

Currently, agri-environment schemes, such as agroforestry and the practice of reserving small patches of semi-natural habitat (cultural elements such as hedgerows or terraces) are applied in mosaic croplands. Precisely, the objective of these agri-schemes is to find a balance between agricultural production systems and the cost to the environment. However, these schemes have been failing due to their lack of landscape-scale perspective. At present, agriculture is expected to be 'multifunctional', i.e., to produce food and to provide environmental, social, and cultural benefits at multiple scales. A good move in this sense would be to 'develop' a spatial (rural) landscape planning based upon a mosaic of land uses/cover. The singularity of the rural landscape of *Segura*, characterized by olive groves on slopes and mountainous terrain along with large areas of different types of vegetation and their particular location within a Nature Reserve, limit the expansion of agricultural areas. Fleskens et al. (2009) highlight that Sloping and Mountainous Olive Plantation Systems (SMOPS) cannot compete with better endowed plantations in lowland regions in the narrowly productive sense. For this reason the concept of multifunctionality is particularly relevant for future development of olive groves on mountainous terrain in *Segura* and for the conservation of heterogeneous landscape structures.

CONCLUSION

In rural environments with a long history of human activity, very fine adjustments can take place between culture and nature. This results in a rural landscape characterised by a heterogeneous mosaic of land uses with varying degrees of ecological maturity, which in turn results in a well-connected network of habitat patches (Schmitz et al. 2007). These heterogeneous landscapes maintain the functioning of ecological processes by means of horizontal flows of material and energy among its components (Rescia et al. 2008). The characteristics of these flows (as direction or magnitude) are conditioned by the heterogeneity of the territory. In the rural landscape of *Segura*, maintaining a suitable level of spatial heterogeneity ensures its functionality (functional landscape heterogeneity *sensu* Fahrig et al. 2011) and, then, its multifunctional character from the ecosystem function point of view (i.e., landscape services) and in relation to the diversity of land-uses. This functional heterogeneity can also influence a variety of ecological responses, including animal movement, population persistence and species interactions (Fahrig et al. 2011).

The *Segura* rural landscape, probably due to its unique topography and situation within a protected area, has shown little transformation in the last 50 years. Controlled expansion of agricultural areas without replacement of natural vegetation in these heterogeneous rural landscapes, involves a reasonable degree of agricultural production and maintenance of optimal conditions for conservation of biodiversity and agro-biodiversity.

We therefore recommend the abandonment of less productive farmland and spatial landscape planning based on the 'land sparing' alternative (Green et al. 2005). This farming option involves interventions aimed at ensuring a high production level by means of agricultural intensification on existing farmed lands, as well as preventing transformation (or permitting restoration) of natural or other desirable habitats. To this end there is a vital need to conserve remnants of natural vegetation at the landscape scale to ensure a successful agro-environmental model for reasonable agricultural production and optimal conservation of biodiversity.

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