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Recent land use and land cover changes in Spain across biogeographical regions and protection levels: implication for conservation policies

ABSTRACT

Land use and land cover change is a major component of global change, which directly alters habitat composition, biodiversity and ecosystem functioning. The regional analysis of land use and land cover changes in heterogeneous landscapes can be masked by spatial variations caused by both bioclimatic and socioeconomic factors. Recognizing these influences, however, can be critical for designing conservation policies suited for each region. In this study, we examined the main processes of land cover and land change in Spain during *c.* 20 years (1987-2006), using CORINE land cover maps and five spatial frameworks of comparison based on biomes (temperate and Mediterranean) and protection levels (Nationally Designated areas, European Natura Net 2000 and unprotected areas). We observed a high persistence (*c.* 93%) throughout Spain, but with important anthropization processes and internal changes in natural areas -which experienced a slight decrease- while, agrarian areas remained almost stable. However, there were significant differences in the occupation, intensity and direction of change depending on the biome and protection level. The Mediterranean region had lower persistence and higher anthropization processes than the temperate region, suggesting a high vulnerability to land use and land cover changes for natural habitat and related species. Overall, we observed a lower intensity of anthropization processes in protected areas, increasing the persistence of natural and agrarian areas, key habitats for species conservation. The highest persistence of natural areas corresponds to Nationally Designated protected areas, while in Natura Net 2000 we found the highest agrarian areas persistence. Nevertheless, Natura Net 2000 had the largest increase of artificial surfaces as well as the highest internal processes of change in natural areas derived from disturbances. The observed trends in this study suggest the importance of effective management plans and conservation measures that ensure both habitat and species conservation, especially in the

Mediterranean region. In the case of Natura Net 2000, where traditional agricultural and livestock activities had a larger importance, it would be advisable to definitively implement the pending management plans, feasible and compatible with local human activities.

***Keywords**:* Conservation; Land use and cover change; Spain; Protected areas; Biomes; Natura Net 2000; Systematic transition.

1. INTRODUCTION

Land use and land cover change (hereafter LUCC) is one of the main drivers of global change (Foley et al., 2005; Turner et al., 2007). The impacts and consequences of LUCC directly affect human well-being through changes in environmental conditions such as land degradation (Figueroa and Sanchez-Cordero, 2008; Sánchez-Cuervo et al., 2012) and modifying key ecosystem services such as net primary productivity (e.g. Haberl et al., 2007) and carbon storage (Van Minnen et al., 2009). Moreover, LUCC directly threatens biodiversity through habitat modifications, causing species losses due to both habitat loss and fragmentation (Fahrig, 2003; MEA, 2005; Ojima et al., 1994). Changes in habitat and species composition could strongly alter ecosystem functioning and the related services provided by natural ecosystems (Laliberte and Tylianakis, 2012; Mace et al., 2012). Thus, in human-dominated landscapes, conservation policies using a biogeographical perspective are critical to ameliorate the potential negative effects of global change in biodiversity and ecosystem functioning (Foley et al., 2005; Heller and Zavaleta, 2009).

Monitoring studies, which imply long-term observations and mapping of LUCC, are critical to improve our understanding and assessment of the extent, dimensions, consequences and causes of LUCC and, thus, predict future trends and recognize critical or vulnerable locations and scenarios (Loveland et al., 1999 and 2004). This kind of research constitutes an important tool for decision-making in conservation and environmental assessment (Ruiz-Benito et al., 2010; Sánchez-Cuervo et al., 2012). However, many monitoring LUCC studies lack a comprehensive outlook integrating its different components, and traditionally have focused exclusively on some specific processes such as deforestation (e.g. Marsik et al., 2011). LUCC results from complex interactions between human activities and ecological processes, including diverse processes from urban settlement and agricultural intensification to land abandonment and desertification (Gallant, 2004).

1.1 The spatial component of land use and land cover change

LUCC is a rare and local event (Sohl et al., 2004), spatially and temporally variable, frequently clustered in space or particularly intense in some periods (Loveland and DeFries, 2004). Although the changes generally occur at the local scale, there are cumulative impacts at broader scales, even globally (Loveland et al., 1999). Most of the studies have been developed at the local scale because there is a greater availability of accurate and reliable spatial data for small areas, but since the '70s the development of remote sensing techniques have allowed a growing number of mesoscale and global studies (Sohl et al., 2004). For this reason, there is an increasing interest in using multiple spatial and temporal scales, which requires making stronger links across scales, with integrative and complementary studies between macro and microscale (Olson et al., 2004). Global and regional analysis help to identify change hotspots and to define national or regional policies, while complementary local analyses can confirm or revise the results obtained at broader scales, trying to inform and guide effective local management decisions and programs (Wilbanks and Kates 1999).

The main problem of large-area assessments at global, national or regional scales or for highly heterogeneous landscapes is that they easily mask critical sub-global or sub-regional variations (Lambin and Geist, 2006). For this reason, in order to properly understand the geographical variability of a given phenomenon, it is common to use spatial stratifications or breakdowns to separately analyze the objective of study (Sohl et al., 2004). These spatial frameworks can be defined using diverse criteria or interests such as administrative boundaries, ecological regions, watershed or protection categories (Loveland and DeFries, 2004). Furthermore, the use of these types of 'regional' frameworks to quantify LUCCs could be important in order to better understand the potential consequences of land management policies, whose suitability and manner of implementation vary regional or locally, although many of them are developed and designed in fact at national or international level (Gallant et al. 2004).

1.2 Objectives and hypotheses

In this study we assessed, for the first time, 20 years (1987-2006) of LUCC throughout Spain quantifying differences in the direction and intensity between two kinds of spatial frameworks: biomes and protection categories. We studied LUCCs using a comprehensive outlook considering all the terrestrial land uses/covers, from forest and natural areas to intensive and traditional agrarian lands and artificial surfaces, and proposing a new simpler classification of land cover flows. We analyzed the interaction between the three primary land use/cover classes; (1) artificial, (2) agrarian and (3) natural surfaces, as well as the persistence and the primary change processes: (1) anthropization, (2) naturalization, and (3) internal changes in natural areas. This approach is also an approximation to the relationship and interchanges between the rural (natural an agrarian) and the urban system. Moreover, the statistical methodology applied allows identification of the transitions that are systematic or different from random processes.

The first framework used is based in ecological and/or biogeographical regions, comparing the temperate and Mediterranean biomes present in Spain. We hypothesized that the Mediterranean biome could present higher anthropic pressure (e.g. more population density and industrialized areas, higher tourism) and larger climatic constraints (e.g. less water availability, more intense drought) than temperate biome, leading to higher LUCC rates, for example in some processes related with anthropization and degradation, and, therefore, increased vulnerability of the ecosystems (Schröter et al., 2005). The biodiversity of some Mediterranean ecosystems is closely related to traditional human management such as agriculture, livestock, or silvopastoral systems (Blondel and Aronson, 1995; OSE, 2010; Scarascia-Mugnozza et al., 2000), so abrupt changes in these uses and activities may incur a loss of biodiversity.

The second type of frameworks is based in comparing three basic protection levels with different implications for habitat conservation: (1) Nationally Designated Protected Areas, hereafter “NDP”; (2) European Natura Net 2000, hereafter “Nn2000” and (3) Unprotected Areas, hereafter “Unpro”. We hypothesized that the stricter and more demanding conservation measures in the NDP areas could imply the least land use and land cover changes, a higher persistence and larger naturalization processes. Meanwhile, LUCC trends in the European Natura Net 2000 (Nn2000) could be different, because in these protected areas the management plans have not been totally implemented and the traditional agricultural and livestock activities play a more important role than in NDP (Molina et al, 2007; WWW España, 2012). Finally, in unprotected spaces, agricultural areas predominate and changing trends could be very different from protected areas (i.e. a greater rate of anthropization processes such as urbanization).

1.3 Background: biogeographical regions and protected areas in land use and land cover change studies

Biogeographical regions, which includes biomes and ecoregions at more detailed levels, could be the basis for designing effective conservation policies and for the establishment of priorities at the national level, because they comprise similar environments, biological communities and biodiversity patterns (Olson et al. 2001; Groves et al., 2002). They could be considered as conservation units for management and planning (Olson and Dinerstein, 2002) as well as for the evaluation of land-cover and land-use dynamics at large spatial scales or in heterogeneous landscapes (Gallant et al., 2004). In LUCC research there are several examples throughout the world using ecoregions, e.g. Sleeter et al. (2013) in the United States, Sánchez-Cuervo et al. (2012) in South America, Falcucci et al. (2007) in Europe or Tappan et al. (2004) in Africa.

On the other hand, protected areas are fundamental tools for conservation of natural and traditional areas in intensive landscapes (Foley et al., 2005). In fact, although protected areas are widely used as a tool for habitat preservation and for maintaining ecological integrity (Turner et al., 2007), the different LUCC trends in different protection levels is not well known. Depending on the protection status or category, the level of implementation of the conservation management and the types of regulations and legislative instruments, there could be differences in the intensity and even in the direction of land use and land cover changes (Ruiz-Benito et al., 2010; Figueroa and Sanchez-Cordero, 2008). Different studies have assessed and monitored directly or indirectly the effectiveness of protection (e.g. Andam et al., 2008; Bhagwat et al., 2001; Chape et al., 2005) using the comparison with non-protected areas (e.g. Alo and Pontius, 2008; Nagendra, 2008; Ruiz-Benito et al., 2010), or applying a buffer or equivalent non-protected surrounding area (e.g. Bruner et al., 2001; Figueroa and Sanchez-Cordero, 2008; Mas, 2005). In most of them the final objective is the protection of biodiversity. However, there is a need to assess the effective management of protected areas (Bonham et al. 2008; Leverington et al. 2010), because some of them (the so-called paper parks; Hocking et al., 2000) do not have real attempts at effective management, for example financing and planning adequate infrastructures, staff and conservation activities.

2. MATERIAL AND METHODS

2.1 Study area

The study area comprises the whole Spanish territory (506,723 km^2), which covers a large area of the Iberian Peninsula from cool temperate to arid Mediterranean regions and the Balearic and Canary Islands (Costa et al., 1997). Spain is one of the European countries with the greatest diversity of ecosystems, habitats and natural species, housing over more than half of the species of vertebrates and vascular plants, a high number of endemism and 65% of the priority habitats of the European Union (OSE, 2010). Within its territory, four biogeographic regions of the seven existing in the 27 member states of the European Union can be found (EEA, 2002-2012). To these high diversity levels the geographical location at mid-latitudes as a crossroads between Africa and Europe and the Atlantic Ocean and Mediterranean Sea could also contribute, with a large environmental heterogeneity with varied and favorable climates and the existence a high number of mountain ranges, which have worked as glacial refuges and isolation areas of endemic species (Hampe and Petit, 2005).

2.2 Land use and land cover data, biomes and protection levels

We used the European CORINE (Coordination of Information of the Environment) Land Cover project (Heymann et al., 1994), hereafter CLC, which is a wall-to-wall land coverage for the whole territory of EU Members with a scale of 1:100 000, a minimum mapping unit (MMU) of 25 ha, a minimum width of linear elements of 100 m and a geometric and positional accuracy of at least 100 m. CLC use a hierarchical nomenclature in three levels, with 44 land use and land cover classes at the third level, that have not changed since the implementation of the first CLC inventory and which is homogeneous through Europe (Bossard et al., 2000; EEA, 2007; see further information about CLC specifications in Appendix A1, included thematic and geometric quality). The CLC specifications result of a trade-off between the scale and spatial detail needed at European level and the thematic precision (number of classes) previously defined (Perdigao & Annoni, 1997). These specifications make the choice of CLC appropriate for national environment management and design of land uses policies, as well as for the study of regional LUCCs (e.g. in Spain OSE, 2006 and 2010). However, the relatively small scale of the land use and land cover information provided by CLC may mask some small change processes (Büttner et al., 2004), as well as the inherited geometrical and thematic errors may have some influence on our results. Nevertheless, given the large-scale of our study area and the thematic simplification applied by reclassification, we considered that the amount of errors is not excessive and do not prevent detecting tendencies at the scale of protected or biogeographical areas in Spain.

From the three versions available in CLC we selected the first (revised CLC90, 1987) and the last dataset (CLC06, 2006) in order to have the longest temporal extension (20 years, from 1987 to 2006). We used two different levels of aggregation of land use and land covers: eight categories of

LEAC classification (Land and Ecosystems Accounts) based on an aggregation of the third level of CLC, particularly useful to global and ecological analysis (EEA, 2006; Gómez and Páramo, 2005), and three primary surfaces or land classes proposed in this study: (1) artificial, (2) agrarian and (3) natural (see Table A.1 in Supplementary Material to understand their composition). CLC nomenclature does not clearly distinguish between the concepts of land cover and land use, using in fact both approaches, or being controversial for some categories (see e.g. Feranec et al. 2007). CLC classes are distinguished in the satellite image based mainly upon physical and physiognomic attributes (i.e. land cover), especially natural surfaces. However, artificial surfaces and agricultural areas are also discerned by functional attributes as the use and, therefore, are related to land use (Perdigao & Annoni, 1997; Feranec et al. 2007). In addition, there are some mixed and non homogeneous categories which made the distinction based only in land cover difficult, as non irrigated arable lands, complex cultivation patterns, land principally occupied by agriculture with significant areas of natural vegetation or agroforesty systems. For these reasons we decided to use the term land use and land cover through the entire manuscript.

Biomes were obtained from the map of WWF-Terrestrial Ecoregions of the World (TEOW) from Olson et al. (2001). Although there are other proposals in Spain defining diverse types of biogeographic regions as Elena-Roselló (1997) we selected WWF-TEOW because is a global map internationally accepted, which clearly differentiate the limit between the two biomes in Spain. Further information about WWF-TEOW and the correspondence between ecoregions in Spain and the biomes and realms, as well as with the Map of the Biogeographic regions in Europe (EEA, 2002-2012) is explained in the Supplementary Material, in Appendix A.2, Table A.2 and Fig. A.2. Most of the Spanish territory (85.5%, see Table 1) is found in the Mediterranean biome ("Mediterranean Forests, Woodlands and Scrub") and the remaining 14% (Table 1) belongs to the temperate biome ("Temperate Broadleaf and Mixed Forests") which is located in the northwest and along the Cantabrian north side of the Iberian Peninsula and the Pyrenees mountains (Fig. 1). Some ecoregions in Spain are included in the WWF Gobal200 list as priority targets for biodiversity conservation (see details in Appendix A.4 and Table A.2 in supplementary material; Olson et al. 2001; Olson and Dinerstein, 2002; WWF, 2000). In Spain, all the Mediterranean ecoregions and also the temperate ecoregion of “Pyrenees conifer and mixed forest” has been assigned a critical or endangered status for conservation. The Mediterranean Basin is one of the 25 world biodiversity hotspots where exceptional concentrations of endemic species are undergoing exceptional loss of habitat (Myers et al., 2000), the only one of importance being in Europe along with the Caucasian area. Several studies agree that this region is particularly vulnerable to global and climate change (Schröter et al., 2005) and suffers a great anthropic influence and pressure.

We grouped all the categories of protected areas existing in Spain in three potential and basic protection levels (see Fig. 1 and further methodological details in Appendix A.2): (1) Nationally Designated Protected areas or “NDP” (BDN, 2009), (2) Natura Net 2000 or “Nn2000” (BDN, 2007 and 2009b), and (3) unprotected areas. The NDP areas are those designated by national or regional legislation (EEA, 2011) using some of the numerous existing figures (48 different ones, including national or natural parks, forest or natural reserves, protected landscapes, etc.). Nn2000 is a European ecological network composed of sites designated under the 1979 European Birds Directive (Special Protection Areas, SPAs) and the 1992 UE Habitats Directive (Sites of Community Importance, SCIs, and Special Areas of Conservation, SACs). In total, 28% of the Spanish national territory belongs to a protected area (Table 1). In this study, we classified the protected areas as Nn2000 when there was no overlap with NDP (Fig.1 and further methodological details in Appendix A.2 and Figure A.1), finding that 12% of the country is NDP area and 16% exclusively as Nn2000. Natura Net 2000 has contributed greatly to increasing (doubling over) the protected area during the period studied, especially since 1997 (Figure A.1). For the initial date of this study (1987) the area under protection in Spain was lower than 2% of the whole territory (Figure A.1, 1.3% and 0.3% for NDP and Nn2000, respectively), but generally areas of high interest for habitat and species conservation are selected to be protected. Finally, for this study we have taken a sample of the unprotected areas such as is proposed in several studies (e.g. Bruner et al., 2001; Figueroa and Sanchez-Cordero, 2008), selecting only the unprotected areas are found around a 10 km buffer from all the protected areas (NDP and Nn2000). However, practically all unprotected areas (94.6%) are indeed inside of this buffer, and only the 5.3% of them are at more than 10 km away from protected areas.

2.3 Land use and land cover changes and systematic transitions

The most conventional method used for detecting changes in categorical variables as land use and cover is based on the transition matrix between maps from two dates of a given period (e.g. Alo and Pontius, 2008; Pontius et al., 2004; Falcucci et al., 2007): in the columns the categories at the initial time (t_0, in this study 1987) are displayed and in the rows the categories at the final time (t_1, in this study 2006) are displayed. Entries on the diagonal indicate proportion of the landscape that shows the persistence of each category (i.e. no changes) and entries off the diagonal indicate transitions between land use/cover categories (see as example Tables A.4 in supplementary material).

Based on the transition matrix for the 8 LEAC classes, we created a classification of potential land cover changes (8×8 = 64 possible one-to-one changes) grouping land cover flows (LCF; Fig. 2 and Table 2). This classification is a more comprehensive way to analyze land use and land cover changes, in a similar way to the LCF classification created by EEA which classifies land use and land cover changes between the third CLC level (44×44 = 1936 possible changes) (EEA, 2006; Gómez and Páramo, 2005). The proposed classification of land cover flows in Fig. 2 and Table 2 is much simpler and has 9 groups of processes, in turn grouped in 4 primary processes: (1) anthropization processes, (2) processes to higher naturalization, (3) internal changes in natural areas and (4) persistence or no-changes. Anthropization, is commonly considered in ecology and geography as the conversion or adaptation of the environment or landscape to meet human needs. Specifically, in the present study we considered anthropization as the transition towards artificial surfaces (urbanization), agrarian creation from natural areas, simplification of agricultural areas and internal changes between pastures, crops and arable lands (see Fig. 2 and Table 2). In the Mediterranean certain agricultural categories (e.g. sylvopastoral systems) includes traditional and cultural landscapes which have been created and maintained by human activity linked to abiotic complexity and high diversity levels (Blondel, 2006). Changes towards these traditional landscapes are related with the process 122 (see Fig. 2 and Table 2). However, the rest of anthropization processes imply the loss of both natural and semi-natural habitats towards more intensive in human uses (i.e. agricultural or artificial).

Vectorial datasets of land cover, biomes and protected areas (Fig. 1) were incorporated into the geographic information system ArcGIS 10 (ESRI Inc., Redlands, CA, USA). We reclassified and aggregated 44 CLC classes in the generic 8 LEAC classes, as well as ecoregions in their corresponding biome and the 50 protection categories in the 3 final protection levels. The 1987 and 2006 land cover maps were clipped for each protection level (NDP, Nn2000 and Unpro) and biome (Mediterranean and temperate) obtaining 10 vectorial maps (five from 1987 and five from 2006) which were converted to raster format with a 25 m. pixel resolution in order to develop a cell-based transition-matrix analysis using cross-tabulation tools of the Spatial Analyst Toolbox in ArcGIS (ESRI Inc).

From the transition matrix (the traditional cross-tabulation matrix) developed for each one of the five study areas (i.e. 3 protected levels and 2 biomes), we calculated the initial and final surface for each category and different indicators proposed by Pontius Jr. et al. (2004) as net change (*NC*), gains (*G*) and losses (*L*) (see Table 3 and Eqn. (1) to (4) in Appendix A.5). From this original transition matrix we calculated and derived secondary matrices with percentages of stable/persistent areas and the changes/transitions over the total area of each study area (see Table 2 and numbers in bold in Tables A.3 in supplementary material), as well as matrices with percentages of each category over the area on the initial date t_0 (see numerical values of Fig. 3 and Tables A.4 in supplementary material) which are obtained by dividing the area of change from cover *'i'* to cover '*j*' in the period from t_0 to t_1 by the total area of cover '*i*' at t_0. This value is interpreted as the probability that a land cover 'i' has to change into '*j*', or remain in the same state, in a single period of time (t_0-t_1), which in this study is 20 years.

Analyses based on conventional matrices do not specify whether these changes are systematic, i.e. if they occur in a different way from a random process. For that, we used Pontius Jr. et al. (2004) methods proposed to identify systematic transitions (i.e. those different from random processes), which are based on estimating the expected gains and losses and comparing them with those observed (see equations (5) and (6) from Appendix A.5). Expected gains and losses depend on the size of the categories and the value of the transition. Random gains from other categories occur if those categories are replaced proportionally to their area in the initial time (t_0) If not, it is a systematic transition. Similarly, random losses from other categories occur if they are replaced by those categories proportional to their sizes at the final time (t_1) If not, it is a systematic transition. The systematic transitions matrices were calculated both in terms of gains and losses for each protection level and biome (Tables A.3 in the supplementary material).

There are two basic methods of comparison of one transition with respect to the "random transition" (i.e. expected change) (Pontius Jr. et al., 2004). The first is the subtraction or the simple difference between the observed and the expected change (hereafter *D*), which indicates the size change due to the systematic transition (Table 4). The second is the ratio between *D* and the expected change (hereafter *R*), which indicate the relative strength of the systematic transition (Table 5). *R* is highly influenced by the expected value and the size of the category involved. We considered a transition as systematic when it appears prominently in both matrices (i.e. gains and losses), with large values different from zero in *D* or *R* and with the same direction of change. Thus, a transition is systematic when either the *D* or *R* is positive for both gains and losses (higher than would be expected from a random process) or when *D* or *R* is negative (lesser than would be expected) for both gains and losses (Alo and Pontius, 2008).

3. RESULTS

3.1 General trends and common characteristics for all study areas

Before analyzing the observed differences between protection levels and biomes, some general trends that are common to the five study areas should be highlighted. Although artificial surfaces account for a very small percentage (less than 3% in all areas, Table 3), they were the land cover type which most widely and intensely increased in all of them (see Table 3 with values by zone, but relative net change was *c.* 51% for all Spain between 1986 and 2006). In contrast, agricultural areas remained almost stable (-0.18% of net change for all the country), although arable lands and crops (ARA) decreased and agricultural mosaics (MOS) increased. Meanwhile, natural surfaces experienced a slight decrease, but greater than the agrarian areas (-1.4% vs. -0.18% for all Spain), although with differences according to the cover type, as the transitional woodland shrub (TRW) which had significant growth over 4% (Table 3), while on the contrary, standing forest (FOR), and open spaces with little vegetation (OPEN) and especially the natural grassland, mesophilic scrubs and sclerophyllous vegetation (GRSH) decreased. On the whole, a high level of persistence is appreciated in Spain (over 93% of the total, Table 2). Facing this persistence, the most predominant change processes are the internal changes between natural covers (group 3 in Table 2), followed by the anthropization processes (group 1 in Table 2) and in the last place by naturalization processes (group 2). These processes and tendencies can be appreciated more clearly in Fig. 4. Among all the anthropization processes in Spain, the most important was the transformation of natural areas in agrarian covers or uses (group 12 of Table 2) which tend to be systematic with a negative sign, i.e. they are lower than expected (Tables 4 and 5). Regarding agricultural abandonment to natural surfaces (group 23), a higher variability was observed and no clear patterns across protection levels and biomes. Finally, internal natural changes are grouped into two main types (Table 2 and Fig.2 and Fig. 4). First, the "successional" processes (group or code 31) comprising recovery processes, forest densification or shrub encroachment, and second, the processes derived from “disturbances” (group

32), which involve a greater simplification, degradation or decline of natural covers (see Table 2). For the internal changes in natural areas different trends were found by zone, although in all them higher rates of successional processes were experienced (Table 2), presenting a more intense and systematic number of transitions (at least four, see Tables 4 and 5).

3.2 Land use and land cover change differences between biomes

Significant and substantial differences in land use and land cover structure and changes between temperate and Mediterranean areas were observed. In the temperate biome there was a higher persistence of land use and cover (94.8%, Table 2), and this was reflected both in natural and agrarian classes (Fig. 3 and Tables A.4 in the supplementary material). While in the temperate biome, natural areas were dominant (71%), in the Mediterranean agrarian covers were the most spread (54%). However, in the temperate biome, agricultural areas decreased slightly more (-0.4% Table 3, especially crops and pastures), but meanwhile, natural surfaces were more stable to external flows (Fig. 3) and decreased to a lesser extent, even observing an increment in forests (0.3%, Table 3) which is an exception to other areas analyzed in this study. However, in terms of natural internal conversions, larger changes were found than in the Mediterranean biome (3.7% vs 2.8%, Table 2), but with a very favorable and positive balance towards succession versus disturbances (2.16% vs. 1.52%, Table 2) especially towards standing forest and shrublands (Fig. 3 and Tables 4 and 5). Although artificial surfaces occupied less surface and increased to a much lesser extent than in the Mediterranean biome (25% versus 55%, Table 3), we found this category was less stable (91% vs. 98%, Fig.3a). In addition, some transitions towards urbanization from pastures and crops were particularly systematic and important in proportion, although an opposite process like the reconversion from artificial areas to mosaic farmlands also was (Fig. 3 and Table 5). In the temperate biome, urbanization reached similar rates to the transformation of natural areas in agrarian covers (0.4%, see group 1.1 and 1.2 in Table 2), which were, however, the most important type of anthropization process in the Mediterranean.

In the Mediterranean biome, anthropization and naturalization processes were higher than in the temperate biome (2.4% and 1.3% respectively, Table 2 and Fig. 4). Particularly important and systematic were the processes related to encroachment and sprawl of shrubs (either because of a positive or a negative evolution) and disturbances (e.g. degradation, regression; Fig. 3a). For example, the transition from standing forest to shrub and grasslands was systematically negative in protected areas and the temperate biome, but in unprotected areas and the Mediterranean biome it was positive, and therefore higher than expected (Table 4 and 5). The difference between succession and degradation was much smaller than in the temperate biome (1.5% and 1.3% versus 2.26% and 1.52%, Table 2), which in contrast is more favorable to the succession. On the other hand, arable land and crops decreased to a lesser extent than in the temperate biome (-1% vs. -3.1%, Table 3), and although the pastures and meadows were much more abundant in the temperate than in the Mediterranean biome (7% versus 0.3%, Table 3), they experienced a significant increase in the Mediterranean biome in contrast to the decline suffered in the temperate one (2.8% versus -3%, Table 3). Among the naturalization process, the agricultural abandonment towards natural areas and the semi-naturalization or "disintensification" of agrarian areas (e.g. ARA-MOS and PAS-MOS) were higher in the Mediterranean than in the temperate biome (Fig. 3, Fig. 4 and Table 4). However, opposing processes of agricultural intensification were also systematic and higher in the Mediterranean biome than in the temperate one (e.g. MOS-ARA Table 4). The internal changes between agrarian covers and land uses are more important in the Mediterranean than in the temperate biome.

3.3 Land use and land cover changes on different protection levels

In both types of protected areas (NDP and Nn2000) natural areas were the largest land cover types (81% of the total area of NDP and 68% of the Nn2000, Table 3), while in unprotected areas (Unpro) the anthropic covers, considering both agricultural and artificial, occupied larger areas (61% of the unprotected surface, Table 3). Moreover, in protected areas the interchanges between natural areas were the ones that affected larger areas (Fig. 4), especially in the Nn2000 with 4.6% versus unprotected areas with 2.5% (Table 2). In addition, some naturalization processes, such as agricultural abandonment were important (see groups 231 and 232 in Table 2). Protected areas were experiencing more important changes in natural areas in favour of succession (Table 2 and Fig. 4) and the systematic "regressive" transitions were less intense (see group 32 in Tables 4 and 5). The most important transitions for all the areas were observed between transitional woodland shrubs and forest in both directions, though mostly in favour of the forest (Tables 4 and 5 and Fig. 3). Finally, the largest land use and land cover change rates from artificial surfaces to natural areas occurred in protected areas, particularly towards shrubs (see Fig. 3B, transition A-TRW). Although these rates are not very high (1.8% and 2.3 % for NDP and Nn2000, respectively, see Fig. 3B), there is a high contrast with unprotected areas (less than 0.4%, see Table A.4.c. in the supplementary material) for these naturalization processes.

In the NDP, the total rate of change was lower than in Nn2000 and Unpro (5.1% vs. *c.* 6.6%, Table 2). Natural surfaces were even more persistent and presented fewer changes, unlike agricultural and artificial surfaces (Fig. 3b). Although natural surfaces in NDP have decreased (-0.3%, Table 3), especially standing forests, grassland and shrubs, they did so to a lesser extent than in the Nn2000 and unprotected areas (-0.5 and *c.* 2% respectively, Table 3). Besides, the difference between succession (group 31) and disturbances (group 32) is higher in NDP (0.6% in favour of succession) than in the Nn2000 (0.06%) and than in unprotected areas (0.3%). Naturalization processes altogether were lower in NDP than in the Nn2000 and unprotected areas (0.69%, Table 2), however some of these processes were higher, particularly the conversion from pastures to forest (Fig. 3b). Other processes such as heterogeneisation or semi-naturalization of crops and pastures in mosaics farmlands (ARA-MOS and PAS-MOS) have resulted systematic here (Table 5) or more outstanding (Fig. 3). Finally, the NDP experienced the lowest increases in artificial surfaces (34.6%,

Table 3) and anthropization and urbanization processes from other land use/cover categories (Table 5).

The Nn2000 presents, in some important aspects of LUCC, an intermediate position between the NDP and unprotected areas (i.e. more intense than in NDP and less than in unprotected areas), such as in anthropization processes (Table 2) or in the decrease of natural surfaces (Table 3). In Nn2000, agrarian uses (crops and especially mosaics) occupied larger areas than in the NDP (31% versus 18%; Table 3), and the behaviour of these agrarian classes was more stable and persistent, even compared to unprotected areas (Fig. 3b and Table A.4.B in the supplementary material). In Nn2000, arable land and permanent crops showed the lowest decreases, but mosaics and pastures had the largest increases in surface (Table 3). Naturalization processes were higher than in NDP (0.89% in Table 2), which were due to agrarian abandonment processes (Fig. 3b). In any case, in all of the study areas the agricultural abandonment processes were systematic in a negative way, i.e. lower than expected, but especially in Natura Net 2000 and unprotected areas (Tables 4 and 5). On the other hand, natural covers were less persistent than what was observed in NDP, although not as much as in unprotected areas (see node values in Fig. 3). Most of the changes experienced were due to internal changes between these natural covers, which were larger, more intense and systematic than what was observed in NDP, especially the interchanges between the transitional woodland shrubs and forest (Fig. 3 and Table 4). Although disturbance-derived processes did not exceed the successional processes, the difference with these was very small. In fact, Nn2000 is the area where perturbation processes were most important in comparison with the rest (2.3% Table 2 and see also Fig. 4). Thus, Nn2000 experienced the most important decrease of standing forest, even more than in non-protected areas (-2.4% vs. -1.6%, Table 3), although most of this loss was a transformation to transitional woodland shrubs (Fig. 3 and Table 4 and 5) which experienced the most important increase observed in all the areas (7.5%, Table 3), as well as the open spaces with little vegetation which also increased here unlike the rest of areas where it decreased (1.7% Table 3). Finally, in

Nn2000 we found that artificial surfaces increased dramatically in relative terms to the initial year (68%, Table 3), even more than in unprotected areas and twice the NDP. However, this increase measured over the total area (0.12%) is lower than unprotected areas.

In unprotected areas all anthropization processes were particularly important, even higher than natural interchanges (2.6% vs. 2.5%, Table 2 and Fig. 4), which are the main types of change processes in the other study areas, but here they are less important than in protected areas. Among anthropization processes and in addition to urbanization, the creation of agrarian areas from natural areas were usually important and systematic, as well as the intensification and simplification of the agrarian landscape (Fig. 3b). Artificial surfaces were the most persistent category (97.2% in Fig. 3), but they increased substantially more than in the NDP (51% versus 34%, Table 2), especially from crops and pastures, while natural areas were more unstable (see node values in Fig. 3) and decreased further, especially natural grasslands, shrubs and open areas (-4.8% and -3.8% respectively, Table 3). Furthermore, a large number of interchanges between natural classes were intensively systematic, especially successional processes, sometimes more than in the NDP and even than in Nn2000 (Tables 4 and 5). However its importance in the territory is lesser according to the values of Table 2. In addition, the transition between forest and shrubland/grassland is positive, i.e. higher than randomly expected, while in the protected areas it is negative (Table 4 and 5). Finally, naturalization processes were higher here than in protected areas (1.4% vs. *c.* 0.7%, Table 2 and Fig. 4), especially due to heterogeneisation or semi-naturalization of agrarian areas, counteracting the intensification processes (0.7%). In any case, while agricultural land as a whole has slightly increased in protected areas (0.8%, Table 3), in those without protection it has declined (-0.3%), and more intensively in the case of meadows and pastures (-2.6%, Table 3).

4. DISCUSSION

This study shows the importance of biomes and protection levels in land use and land cover changes (LUCC) as well as for guiding national and European environmental policies for a sustainable territorial management. Biomes and ecoregions can be effective conservation units for management and planning at regional, national and global scales to estimate the level of effort needed and the urgency to set conservation priorities, strategies and actions (Olson and Dinerstein, 2002; Olson et al., 2001). To that end, it is necessary to analyze their sensitivity to disturbances, their biological distinctiveness and their conservation status (Olson et al., 2000). LUCC analysis can be part of this assessment. In this study we observed that the temperate biome experienced a greater presence of natural cover, lower land change rates, and a smaller decrease of natural areas than the Mediterranean. In the protected areas these same patterns are observed. Instead, the Mediterranean region, in contrast with the temperate biome, had larger anthropic surfaces, both artificial as agrarian, and a greater decrease in natural surfaces, higher anthropization processes especially urbanization and higher transformation of natural areas to agrarian areas. Similar trends are observed in unprotected areas. The observed land use and land cover change trends suggest a high vulnerability of the natural habitats in the Mediterranean region due to human pressure, e.g. due to increased population density and urbanisation (Blondel and Aronson, 1995) and increased industry and tourism development (Scarascia-Mugnozza et al. 2000; Underwood et al. 2009). In addition to the human pressure determining land cover changes, diverse Mediterranean ecosystems are highly threatened byclimatic constraints such as severe droughts (Schröter et al., 2005), intense and frequent fires (Pausas et al., 2008), and torrential rainfalls. Land erosion have also increased in the Mediterranean with a high occurrence of fires and torrential rainfalls (De Luis et al., 2003). All these constraints may lead to altered natural communities and land degradation (e.g. Myers et al, 2000; Gritti et al, 2006). The Global 200 (see Appendix A.4) indicated that in the Mediterranean biome, most natural communities have been degraded or permanently altered and they are threatened by habitat fragmentation, frequent fires, intensive grazing, logging, exotic species and the conversion to agriculture, pasture, and urban areas (Olson et al., 2000). In addition the European Environment Agency identifies as main threats to biodiversity of this region the heavy tourism and urbanization pressure especially in coastal areas, the intensification of agriculture in plains, the land-abandonment in mid-mountains, the desertification in some areas and invasive alien species (EEA, 2003). In the Mediterranean zone we observed a greater shrub encroachment and colonization, and a higher impact of the processes related to disturbances, whether natural or human-induced, which lead to a degradation or regression in vegetation communities. These trends have been reported previously in literature (e.g. Blondel and Aronson, 1995; Brouwer et al., 1991, Madrigal-González et al., 2013). However, according to our results, there are other aspects that cannot be defined as negative, at least for species closely related with traditional agrarian activities (Scarascia-Mugnozza et al., 2000): crops have decreased to a lesser extent, pastures and mosaics farmlands have increased and the set of naturalization processes seems to be more important e.g. from homogeneous agrarian areas to mosaic structures or semi-natural agrarian areas as well as agricultural abandonment. Unexpectedly these naturalization processes are also important in unprotected areas. On the other hand, more important internal changes between agrarian uses have been experienced in the Mediterranean. Finally, probably all LUCC trends detected in the Mediterranean biome could have been particularly intense in coastal zones where the tourist and urban pressure have been increasing, and, therefore, it may constitute an important threat for important habitat and species conservation.

In terms of protection levels, there are many indicators of our study that point to the important and positive role of protected areas in favor of certain natural and agrarian habitats of species and in the mitigation of anthropogenic impacts (Figueroa and Sanchez-Cordero, 2008; Ruiz-Benito et al. 2010). This is concluded just when they are contrasted with spaces without protection measures, where all anthropization processes, especially urbanization, were greater, and also where the creation of agrarian areas from natural covers as well as the intensification and simplification of the agrarian landscape were more important. Moreover, the agrarian surfaces decreased, especially meadows and pastures. Instead, in Nationally Designated Protected (NDP) areas the change rate was lower, natural covers were more persistent and experienced lower decreases than the rest of the territory. In these areas, the lowest increases in artificial surfaces and lower anthropization and urbanization processes were also experienced. However, the logical predominance of natural classes in protected areas could explain to a large extent the high rates of interchanges between these covers and, at the same time, the lower naturalization processes.

Between the two levels of protection (NDP and Nn2000) important differences are observed in land uses/covers and in LUCC. In the NDP, there was a positive effect on natural land covers, which are more persistent than in the Nn2000. These results could be due to the fact that there is a more effective and restrictive protection in the NDP, which, in some cases, strongly limits the human activity (EUROPARC-España 2008). In NDP, lesser anthropic and urbanization processes were also noted, but a positive effect was not observed on the agrarian lands (including both agriculture and livestock), which are also important as habitats of species. In many aspects, Nn2000 was found half-way between the NDP and unprotected areas. The peculiarity of Nn2000 was that, although they are protected areas, agrarian areas are more important than in the NDP, having a more stable behaviour or persistence, even compared to unprotected areas. In fact, Nn2000 was where the lowest decreases of the agrarian areas occurred, and some of them even experienced an increase, such as pastures and mosaic farmlands. Furthermore, in the Nn2000, artificial surfaces have increased to a greater extent (% respect to the initial area in 1987), even more than in unprotected areas, which indicates the need for real protective measures and an effective management to alter those processes that can be inconsistent with the conservation objectives and values of the Nn2000.

In this study, when we mention “Nn2000” we are referring to protected areas in the European Network 2000 which do not overlap with NDP. This distinction is scarcely made in literature, or by stakeholders, but this could be necessary for an effective management of protected areas, because in Spain 41% of the Nn2000 coincide or are included as NDP areas and most of the NDP sites (94%) are coincident or included in the Nn2000 (see Appendix A.2 in the supplementary material). The importance to effective management relies in the fact that NDP in Spain have to approve a Natural

Resource Management Plan and a Plan for the Use of Management in each protected area. The approval of these specific management plans enable the declaration of public utility and social interest, and ultimately restrict and limit the activities that could be performed inside NDP depending on the declaration objectives of each protected area (EUROPARC-España, 2008). The NDP areas are one of the strategies for the stricter and more demanding conservation planning. However, these areas with high natural and landscape values, mostly forest lands, have the risk of becoming isolated areas of the economic processes and the transformations of the surrounding areas.

Unlike NDP, the Nn2000 is not a system of strict nature reserves where all human activities are excluded or prohibited. Although they include nature reserves, most of the land continues to be privately owned (the ownership is not changed with the declaration) and the emphasis will be on ensuring that future management is sustainable, both ecologically and economically (EC, 2012). Many areas in the network are agrarian, and a priori, agricultural and livestock activities and even hunting are allowed, especially if they are traditional, because in many cases they are essential for the maintenance of the habitats and species for which they were declared, and for this reason it would be convenient to be subsidized or encouraged. This is the case for some areas of rainfed cereal steppes or mountain pastures with extensive livestock use. Of course, any activity or land change with negative impacts on species and habitats could not be compatible with Nn2000 values and must be evaluated, such as large urban and infrastructures developments, agrarian intensifications from mosaics, transformation from non-irrigated to irrigated surfaces or a large change in the stocking density (WWF, 2008). Other non-traditional activities such as building new farms, camps, agricultural buildings to store tools, roads and tracks or new fences will require environmental impact studies conducted by each regional and local administration. Another important difference with NDP is that in Nn2000 the management and financial instruments are more numerous and flexible, including measures such as contractual agreements, management contracts with private landowners, corporations, or municipalities, and also several financial lines linked to European funds. There is not a unique financial line, so in the management plans it must be specified how it will be financed, how many European funds each area will receive or which conservation measures will be applied (Molina et al., 2007; EC, 2012).

In Natura 2000, there has been a general delay in the management stage and in the approval and implementation of management plans, conservation measures and assignment of resources (WWF, 2012), with consequences on land use and land cover changes. For the reference year of this study (2006) all the Nn2000 sites were declared as SCI (Sites of Community Importance) and/or SPA (Special Protection Areas), but this declaration in a list is only a stage of preventive protection measures, so it can be said that many of them could be, in fact, “paper parks” (Bonham et al. 2008; Hocking et al., 2000). However, unlike unprotected areas, when new developments are planning in a Natura 2000 area there is the obligation to undergo a specific Appropriate Assessment of the negative implications and impacts on habitat types and species, regardless of having or not a management plan approved (article 6.3 of Habitats Directive). Six years after the declaration, member states must transform these SCIs as definitive SACs (Special Areas of Conservation) along with their management plans, starting thereby, the implementation phase. In total, only 9% of the sites of the Natura 2000 network in Spain have approved a management plan (WWF, 2012). The deadlines for approval of the plans and the designation of SACs have expired in all the Spanish biogeographical regions (the last in 2012 for the Mediterranean region), facing serious sanctions from the EU. In addition, the management process and designation of the Nn2000 is not homogenous in the different Spanish regions. Some have oriented at unifying the management according to the current model of NDP, considering it positive that the Nn2000 site is assimilated to an NDP figure. Management plans of Natura 2000 does not have to be the same as those of the NDP (PRUG and PORN), nor be shared in case they coincide or overlap. There is a debate among different groups and organizations about which of the two models (National Designated or European Nn2000) should be the basis of the conservation and management policy, or if both will have to coexist at the same time, according to the characteristics and value of the areas they affect (Molina et al., 2007). Given the different characteristics and problems of the Nn2000 areas which do not overlap with NDP, we think that it would be advisable for them to follow with a different management treatment, not so restricted regarding the allowed human activities as the NDP areas, and using more flexible financial instruments.

5. CONCLUSION

To design and guide effective conservation policies it is needed large scale analyses of land use and land cover changes, covering broad climatic and biodiversity gradients as those found in Spain. However, at this national level the implementation of conservation policies may vary regionally considering potential variations from the results provided at large spatial scales. Therefore, it is particularly useful to use perspectives provided by biogeographical regions, in order to detect its potential vulnerability and identify which processes are threatening habitats and species related. This information is crucial in order to establish conservation priorities and management strategies at the national level, where Mediterranean areas had higher LUCC rates and anthropization processes than temperate regions.

The analysis performed by protection level has also shown marked differences in the intensity of LUCC trends, which seem to be more favorable for the natural habitats in the protected areas: higher persistence of natural and agrarian areas (which are key habitats for species conservation), higher naturalization and successional processes, and lower anthropization levels. However, a lower level of implementation of the conservation policies, management plans and legislative instruments inside of these protected areas may be associated with some of the negative trends detected in the study period (1987-2006). Specifically, an important increase of artificial surfaces and higher disturbance processes in natural habitats were observed in the Natura Net 2000, in contrast with Nationally Designated Protected Areas. It is particularly necessary to pay special attention to LUCC and provide the sufficient resources to fully develop effective management in the Natura 2000, and, therefore approve management plans. It is critical to ensure lower anthropization levels in Natura Net 2000 and achieve the objectives of its declaration, promoting the conservation of a high proportion of territory in order to guarantee habitat and species persistency.

The availability of long-term observations and wall-to-wall maps provided for monitoring projects as CORINE Land Cover, which is developed in 38 countries of Europe, is fundamental to adequately assess habitat conservation and LUCC trends. Although it is not possible to establish cause-effect relationships it allows us to provide large-scale assessment of LUCC trends over *c.* 20 years (1987-2006) and to identify particularly vulnerable areas which should receive specific attention from stakeholders and decision makers.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at: XXXX

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FIGURE TITLES & CAPTIONS

Figure 1. Map of the Spanish biomes^1 and of the protection levels considered (Nationally Designated Areas and Natura Net 2000)

[1] Biome limits are based on the map of WWF-Terrestrial Ecoregions of the World (TEOW) from Olson et al. (2001)

Figure 2. Land use and land cover flows^1 (LCF): processes of change identified based on LEAC classification of the CORINE Land Cover dataset (Gómez and Páramo, 2005).

[1] Numerical codes of processes coincide with those of Table 2 where are defined and explained.

Figure 3. Land use and land cover change graphs of the transition matrices (% of change with respect to the initial area of the class in 1987)^1 by biome (A) and protection level (B)

[1] Transitions are shown only above 1% and those which are greater than 2.5% and 4% are highlighted with thicker lines. In the nodes, in addition to the class label, the percentage of stable or unchanged land cover is indicated for each class. See acronyms of land use classes in Table S1 or in Figure 2.

Figure 4. Percentage of the different LUCC flows . The percentage of change is calculated as the area of the land cover change respect to all the changes within the study region depending on the protection level: (A) NDP (Nationally Designated Areas), (B) Nn2000: Natura Net 2000, and (C) Unpro (unprotected areas), and depending on the biome: (D) Temp: temperate, (E) Med: Mediterranean. Level 1 and 2 are referred to hierarchical codes described in Table 2.