Future land use change dynamics in Natural Protected Areas. Madrid Region case study.

Marta Gallardo[1] and Javier Martínez-Vega[2]
[1]*Department of Geography, University of Concepción, Victor Lamas 1290 Casilla 160-C, Concepción, BioBio, Chile.*
[2]*Institute of Economics, Geography and Demography, Spanish National Research Council, Albasanz 26-28, 28037 Madrid, Spain.*
martgallar@gmail.com, javier.martinez@cchs.csic.es

Keywords: Land use changes, Land use scenarios, Natural Protected Areas, Region of Madrid, Spain.

Abstract: Natural protected areas are declared to safeguard their environment, goods and services. However, sometimes they are affected by land use changes related to human activity, which affects their ecosystem functions and their sustainability. Problems such as fragmentation or low habitat connectivity are some of its consequences. Developing future land use scenarios is essential if a preventive approach to the management of protected areas is to be adopted. In this paper, three different land use change scenarios in natural protected areas in Madrid region are modelled: a "business as usual" scenario, an economic crisis scenario and a green scenario. All protected areas are studied, from National and Nature Parks to Special Areas of Conservation and Special Protection Areas; changes in a buffer area of 5 km around PA are also studied. The CLUE model (based on logistic regression) is used. Biophysical, socio-economic and accessibility factors and incentives and restrictions are considered. In recent decades, the region of Madrid has experienced intense urban and infrastructure development (48,332 ha). Protected areas have been affected by this urbanization process (almost 5,000 ha) and its surroundings (30,000 ha). These findings should alert land use planners and the managers of protected areas to the potential threats.

1 INTRODUCTION

Natural protected areas occupy nowadays 15.4% of the land area and of continental and inland waters, 3.4% of the global ocean area, 8.4% of marine areas covered by national jurisdictions and 10.9% of coastal waters (Juffe-Bignoli et al. 2014). In Spain, from 1990 to 2013 the number of protected natural areas multiplied by 7 and their surface area tripled (EUROPARC-España 2014). Over 27% of the surface occupied by terrestrial ecosystems are protected by national, European or worldwide networks. Within the EU, Spain is the largest contributor to the Natura 2000 network.

In spite of their importance, Protected Areas (PAs) are increasingly under threat from factors such as climate change (Ruiz-Mallén et al. 2015), land use changes (LULC) (Martínez-Fernández et al. 2015), deforestation (FRA 2010), forest fires (Chuvieco et al. 2013), habitat fragmentation (Dantas de Paula et al. 2015), loss of biodiversity (Sastre et al. 2002), propagation of invasive species (Lei et al. 2014), urban pressure (McDonald 2013) and public use (López Lambas and Ricci 2014).

Land-use change is a matter of concern for the scientific community. Spatio-temporal analysis can be used for a number of purposes (Lambin et al. 2001; Moreira et al. 2001; Améztegui et al. 2010; Viedma et al. 2015): (1) to observe land use changes in the past and explore the factors explaining them, (2) to simulate possible environmental and socio-economic impacts, and (3) to assess the influence of political alternatives in order to improve planning.

However, little is known about LUCC trends at different protection levels. Recent studies have focused on analysing changes in protected areas of differing importance and in the unprotected areas around them (Sastre et al. 2002; Romero-Calcerrada et al. 2004; Ruiz-Benito et al. 2010; Hewitt and Escobar 2011; Martínez-Fernández et al. 2015; Hewitt et al. 2016). It is important to simulate future land-use scenarios so that a dual approach can be adopted in preventive planning for protected areas and their surroundings (Martinuzzi et al. 2015). The simulated scenarios and initial knowledge of their consequences for landscape structure could be a good starting-point for discussion and for reaching agreements between local communities and managers of protected areas.

The objective of this paper is to simulate land use in 2025 in PAs and their surrounding areas in the region of Madrid using the free software CLUE, based on logistic regression. LUCC that took place between 1990 and 2006 and the changes expected by 2025 are analysed in order to determine trends and threats arising inside and around PAs.

2 STUDY AREA

The Madrid region covers an area of 8,027 km^2 and in 2016 had a population of 6,436,996 inhabitants (http://www.madrid.org/iestadis, last accessed February 18, 2017). It is the most densely populated region in Spain with about 800 inhabitants /km^2.

In the region of Madrid, PAs occupy 329,164 ha, equivalent to 41% of the region's total surface area (Figure 1).

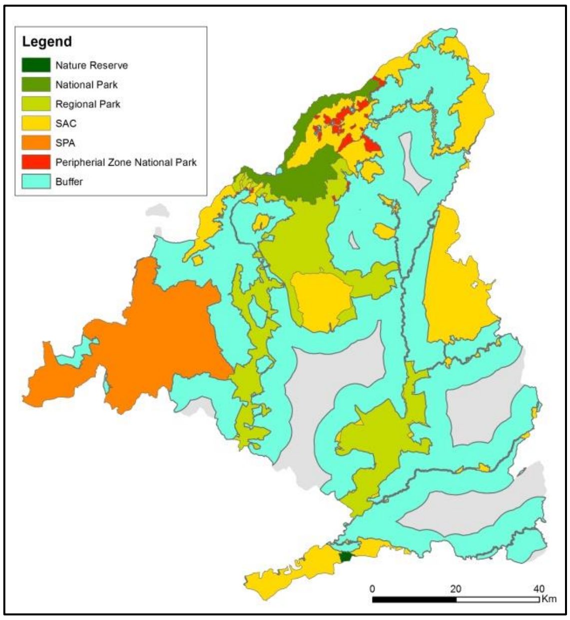

Figure 1: Study area: Madrid region, Spain.

Table 1 shows this PAs, listing them in order of protection – from greatest to least. 15% of the Madrid Region is protected in SACs (Special Areas of Conservation), 12% in Regional Parks (RP), 10% in an SPA (Special Protection Area), about 3% belongs to a National Park (NP) and the remaining 1% is occupied by the Peripheral Protection Zone (PPZ) around this National Park and by a Nature Reserve (NR). All the PAs studied contain terrestrial ecosystems typical of the Mediterranean biogeographic region.

A 5-km buffer zone around all the PAs in the region was took into account. It occupies 372,865 km^2, this is 46% of the region's area. Its aim is to mitigate threats to the PAs and as such it plays a strategic role in the conservation of biodiversity. About 13% of the region's land surface falls outside the scope of the study. Most of it is occupied by the city of Madrid and by other towns within the metropolitan area.

Table 1: Natural protected areas considered in the study.

Protected area	Designation year
El Regajal-Mar de Ontígola Nature Reserve	1994
Sierra de Guadarrama National Park	2013
Cuenca Alta del Manzanares Regional Park	1985
Sureste Regional Park	1994
Curso medio del río Guadarrama Regional Park	1999
Cuenca del río Lozoya y Sierra Norte SAC	1998 / 2014*
Cuenca del río Manzanares SAC	1998 / 2014*
Cuenca del río Guadalix SAC	1998 / 2014*
Cuencas de los ríos Jarama y Henares SAC	1998 / 2014*
Vegas, Cuestas y Páramos del Sureste de Madrid SAC	1998 / 2014*
Encinares de los ríos Alberche y Cofio SPA	1990
Peripheral Protection Zone Guadarrama National Park	2013

* For the SACs, two dates are given in the "Designation year" field. The first refers to the year when the regional government proposed to the EU that the area be declared an SAC. This marked the beginning of their commitment to preventive protection in order to conserve the biodiversity of the area's habitats. The second date is the actual date of the declaration, after which the corresponding management plans were approved.

3 DATA AND METHODOLOGY

Regarding to the information related to PA, two sets of geographical data were selected: the updated perimeters and their corresponding attributes for the Nationally Designated Protected areas (NDP) in the Madrid region and the Natura 2000 Network areas (Nn2000), both downloaded from the Spanish Ministry of Agriculture, Fisheries, Food and

Environment (MAPAMA) web page (last accessed February 1, 2017). In order to find the dates for final approval of the SACs, the cartography was linked with the Common Database on Designated Areas (CDDA) of the European Environment Agency (http://www.eea.europa.eu/data-and-maps/data/natura-6#tab-european-data, last accessed February 1, 2017).

Regarding to the information needed to develop the land use scenarios, maps from CLC project for the years 1990, 2000 and 2006 were downloaded (http://centrodedescargas.cnig.es/CentroDescargas/buscadorCatalogo.do?codFamilia=02113, last accessed February 1, 2017). We did not consider the most recent map (CLC 2012) because it is still under review.

A collection of auxiliary geographic data was taken into account in order to map the driving factors and the restrictive and incentive factors during design of future land use scenarios. A Digital Elevation Model (raster 30 m GMES RDA, EU-DEM) was used to generate altitude and slope maps. Roads, rivers and railway stations (Numerical Cartographic Base 1:100,000, obtained from the Spanish National Geographical Institute) were considered to calculate cost of transport and distances to the city of Madrid, to other cities, to the airport and to the roads themselves. Other information used was the lithological map of Madrid, the map of public-utility forest areas (Regional Government of Madrid), PA zoning in the region (Autonomous Body for National Parks) and specific legislation on land and territorial planning (General Urban Land Plan for Madrid for 1997, Law 9/2001 of 17 July on land in the Region of Madrid, Law 9/1995 of 28 March on measures for territorial policy, land and planning, and Law 3/1991 of 7 March on roads in the Region of Madrid).

CLC vector maps were converted to 50*50m pixel size raster format. To simulate future land use in 2025, a simplification of CLC legend was made, from CLC level 3 to seven categories was made: (1) urban fabric, (2) industrial and commercial, (3) arable land and permanent crops, (4) heterogeneous agricultural areas, (5) forests, (6) shrubs and herbaceous vegetation, and (7) others (open spaces with little vegetation, wetlands and water bodies). Using CLUE three different scenarios were developed: (a) “business as usual” scenario, (b) economic crisis scenario and (c) green scenario. The first one, shows what would happen if the past trend in 1990-2000-2006 were to continue until 2025. The crisis scenario shows what would happen if the economic crisis in Spain and the region of Madrid were to continue until 2025. The green scenario shows what would happen if there were more active reforestation policies and if greater importance were placed on the natural environment. It does, however, take into account that Madrid is an urban region and that built-up areas will continue to grow. This means on the one hand, that greater protection is offered to natural uses than in the past and, on the other, that greater growth is assigned to built-up land. (For more information see Gallardo 2014; Gallardo et al. 2016).

Land use and driving factors were related by means of logistic regressions (LR). Previously, correlations between the selected variables were observed by a Pearson’s correlation analysis. The future demand for each land use was assigned specifying the number of hectares for each land use in 2025, based on what had happened in previous years.

Calibration processes were taken into account in order to improve the scenario results. Taking the sequence of maps 1990-2000 as a base, a simulation of a land-use model in 2006 was carried out and compared it with the real map for 2006. The amount of land-use change, the driving factors used and/or the size or weight of the neighbourhood were changed in order to obtain a better result. For validation, comparisons in terms of quantity and location were analysed. Kappa statistics, K Location (location) and K Histogram (quantity) (Pontius 2000; Van Vliet 2009) was used. Results were compared with a null model and a random model. Values and maps of hits, misses and false alarms were obtained (Eastman 2012; Sangermano et al. 2012). (See Gallardo, 2014)

PA were analysed regarding to their level of priority. Areas that overlapped are classified as areas of greatest protection. In descending order, the level of priority is as follows: (1) Nature Reserve, (2) National Park, (3) Regional Park, (4) SAC, (5) SPA, (6) Peripheral Protection Zone in *Sierra de Guadarrama* National Park.

A 5-km buffer of unprotected area around each PA, joining up areas that are adjacent to each other was established. From this buffer land that might be protected for other reasons (public-utility forest, public waters, roads, etc.) was excluded.

Cross-tabulation matrices (Pontius 2004) were drawn to obtain values and maps of changes between 1990-2006 and 2006-2025, comparing the results with the protected areas depending on their level of priority and with the 5-km buffer.

Table 2 show the reclassification made in order to analyse five different processes: a) Artificialization (ART1 and ART2), b) Agricultural land intensification and natural areas plowing (INT-AGR), c) Agricultural land abandonment and natural vegetation colonization (A-AGR), d) Forest regeneration (FRG), and e) Natural vegetation degradation (DEGR).

Table 2: Cross-tabulation matrix showing the land use processes analysed.

<table>
<tr><td></td><td></td><td colspan="6">t1</td></tr>
<tr><td></td><td></td><td>U</td><td>IC</td><td>AL</td><td>HA</td><td>SP</td><td>F</td></tr>
<tr><td rowspan="6">t2</td><td>U</td><td></td><td>INT-UR</td><td colspan="2" rowspan="2">ART1</td><td colspan="2" rowspan="2">ART2</td></tr>
<tr><td>IC</td><td rowspan="5">NO</td><td></td></tr>
<tr><td>AL</td><td rowspan="2">NO</td><td></td><td colspan="3">INT-AGR</td></tr>
<tr><td>HA</td><td rowspan="2">A-AGR</td><td></td><td colspan="2">INT-AGR</td></tr>
<tr><td>SP</td><td>NO</td><td></td><td></td><td>DEGR</td></tr>
<tr><td>F</td><td>NO</td><td colspan="3">FRG</td><td></td></tr>
</table>

4 RESULTS

Table 3 shows the percentage of total LUCC change that took place between 1990 and 2006 by zone (types of PA and their surroundings), a period of intense change. It shows which processes are more intense in each PA.

Table 3: Principal processes that took place between 1990 and 2006 in protected areas and their surroundings, in percentage of total change.

	ART	INT-AGR	DEGR	A-AGR	FRG
NR	1,01	97,97	0,00	1,01	0,00
NP	0,00	0,00	28,24	0,00	71,76
RP	42,45	13,87	6,08	35,34	1,69
SAC	27,34	11,33	25,03	20,70	14,56
SPA	30,84	4,78	14,59	35,23	15,56
PPZ	40,60	0,00	0,00	0,00	59,40
BUFFER	68,90	4,56	3,32	18,71	3,78

NR Nature Reserve, NP National Park, RP Regional Park, SAC Special Area of Conservation, SPA Special Protection Area, PPZ Peripheral Protection Zone. Artificialization (ART), Agricultural land intensification and natural areas plowing (INT-AGR), Agricultural land abandonment and natural vegetation colonization (A-AGR), d) Forest regeneration (FRG), and e) Natural vegetation degradation (DEGR).

There are large differences depending on the degree of protection enjoyed by the different PAs. The Regional Park, Peripheral Protection Zone, Special Protection Area and Special Area of Conservation were the most affected by the growth of urban areas. In the surrounding area, almost 69% of the change is related with urban growth. During these years, 10% of the urbanization was developed inside PA and 60% in their neighbourhoods.

However, the principal process in the PA with highest degree of protection is the intensification of the agriculture in the Nature Reserve and the forest regeneration in the National Park. Its management plans prioritize these processes. It is also remarkable the abandonment of land and its recolonization by natural vegetation in a context of a traditional dryland agriculture crisis. This process is less intense in the buffer area because most of the abandoned agricultural land is now urbanized.

Tables 4 to 6 shows the percentage of total LUCC change that took place between 2006 and the three different scenarios run to year 2025.

In the “business as usual” scenario (table 4) there is no land use change expected in the Nature Reserve and National Park. Changes in the Regional Park will be related with an intensification of agriculture (51.51% of the total change) and artificialization (38.57%). In the Special Area of Conservation and Special Protected Area will be an increase of colonization of natural vegetation due to land abandonment and also a forest regeneration process. In the surrounding area the most important process will be the artificialization (almost 100% of the total change). It should be noted that, unlike in the past years, there will be not a big increase in the artificialization because restriction on PA planning has taken into account in the scenario development. It is expected that restrictions will be respected in the future. This has not occurred during the period 1990-2006.

Table 4: Principal processes that took place between 2006 and 2025 in the business as usual scenario, in protected areas and their surroundings, in percentage of total change.

	ART	INT-AGR	DEGR	A-AGR	FRG
NR	0,00	0,00	0,00	0,00	0,00
NP	0,00	0,00	0,00	0,00	0,00
RP	38,57	51,51	0,00	9,91	0,01
SAC	55,56	0,00	0,00	25,34	19,10
SPA	0,05	0,00	1,54	88,13	10,28
PPZ	0,00	0,00	0,00	0,00	0,00
BUFFER	99,44	0,00	0,00	0,55	0,00

In the economic-crisis scenario and green scenario there will be no change in the PA with highest protection. However, in the first one artificialization will be the principal process in the Regional Park and degradation will be the most important process in the Special Area of Conservation. It highlights also the change to natural vegetation in the Special Protection Area with an important natural colonization process and in the Peripheral Protection Zone where the only change will be an increase of forest regeneration.

In the green scenario the most important processes in the different PA are related with the abandonment of the agriculture and the regeneration of the vegetation. It is expected that policies promoted by PA managers will encourage these processes

Table 5: Principal processes that took place between 2006 and 2025 in the economic-crisis scenario, in protected areas and their surroundings, in percentage of total change.

	ART	INT-AGR	DEGR	A-AGR	FRG
NR	0,00	0,00	0,00	0,00	0,00
NP	0,00	0,00	0,00	0,00	0,00
RP	99,65	0,00	0,07	0,00	0,28
SAC	0,87	10,20	74,09	12,12	2,72
SPA	0,00	0,00	3,23	87,62	9,14
PPZ	0,00	0,00	0,00	0,00	100,00
BUFFER	98,58	0,03	0,02	1,37	0,01

Table 6: Principal processes that took place between 2006 and 2025 in the green scenario, in protected areas and their surroundings, in percentage of total change.

	ART	INT-AGR	DEGR	A-AGR	FRG
NR	0,00	0,00	0,00	0,00	100,00
NP	0,00	0,00	0,00	0,00	0,00
RP	9,74	0,00	0,00	18,22	72,05
SAC	12,12	0,00	0,00	2,93	84,95
SPA	0,01	0,00	1,19	55,11	43,69
PPZ	0,00	0,00	0,00	0,00	100,00
BUFFER	67,64	0,00	0,00	7,56	24,79

Figure 2 and 3 show the location of land use changes and their processes in the different PA and in its surroundings, between 1990 and 2006, and the expected changes between 2006 and 2025 in the “business as usual” scenario, respectively.

Inside the PA, a change gradient according to its hierarchy is shown (Figure 2). In the Natural Reserve there has almost been no change as a result of its strict regulation. In the National Park there has been an exchange between natural land use classes: natural vegetation losses are associated probably with forest fires, and on the other hand, gains in this land use are related with a policy of promotion of forest ecosystems. It should be noted that the National Park *Sierra de Guadarrama* has recently been declared (2013); however, its mountains were formerly included in the Natural Park of *Peñalara* and in the Regional Park of *Cuenca Alta del Manzanares*, both with an strict legislation regarding to land use changes.

5.000 ha have been urbanized in the three Regional Parks. This change is related with forest losses in the North and with agrarian losses in the South and East of the region. In the Regional Park *Parque Regional del Sureste*, it is noteworthy a forest fire that destroyed almost 200 ha of pine forest in 2003.

SAC near to Madrid have also been affected by new urban, industrial and infrastructure areas. The more distant ones, located in mountain environments, have increased their forest lands related with the agriculture abandonment. In addition, they have also recorded important forest fires: in 1995, a forest fire burned more than 1.000 ha of pine trees in Somosierra.

In this period, one of the most dynamic PA has been the SPA *Encinares de los ríos Alberche y Cofio*, located in the Southwest of the region. More than 1.200 ha of agricultural land has been abandoned. In addition, fires have burned hundreds of hectares of pine forest. Finally, about 600 ha of forest and agricultural land have been urbanized. The largest patch is a new development of single-family homes built near the San Juan reservoir. Since 1990 no agreement has been reached between local and regional governments to approve a management plan in this PA. Local governments have taken advantage and they have modified their urban planning in favor of this type of transitions.

Biggest land use changes are located outside the PA. The buffer registered the largest new urbanizations (more than 30.000 ha). In the north, this new developments are located in former forest ecosystems and in the south they occupy former agriculture lands. PA managers consider this urban pressure as their main threat.

In figure 3 is remarkable the expected progression of forest ecosystems on agriculture lands (almost 4.000 ha) and the natural regeneration of vegetation (almost 500 ha) in the SPA located in the Southwest of the region. This process is also expected to occur in the south of the Regional Park *Cuenca Alta del Manzanares*.

In this PA, 900 ha of urbanization is expected, associated with the accessibility provided by A6 and M607 highways.

In the PA neighborhoods, highlights the expected urban and industrial increase.

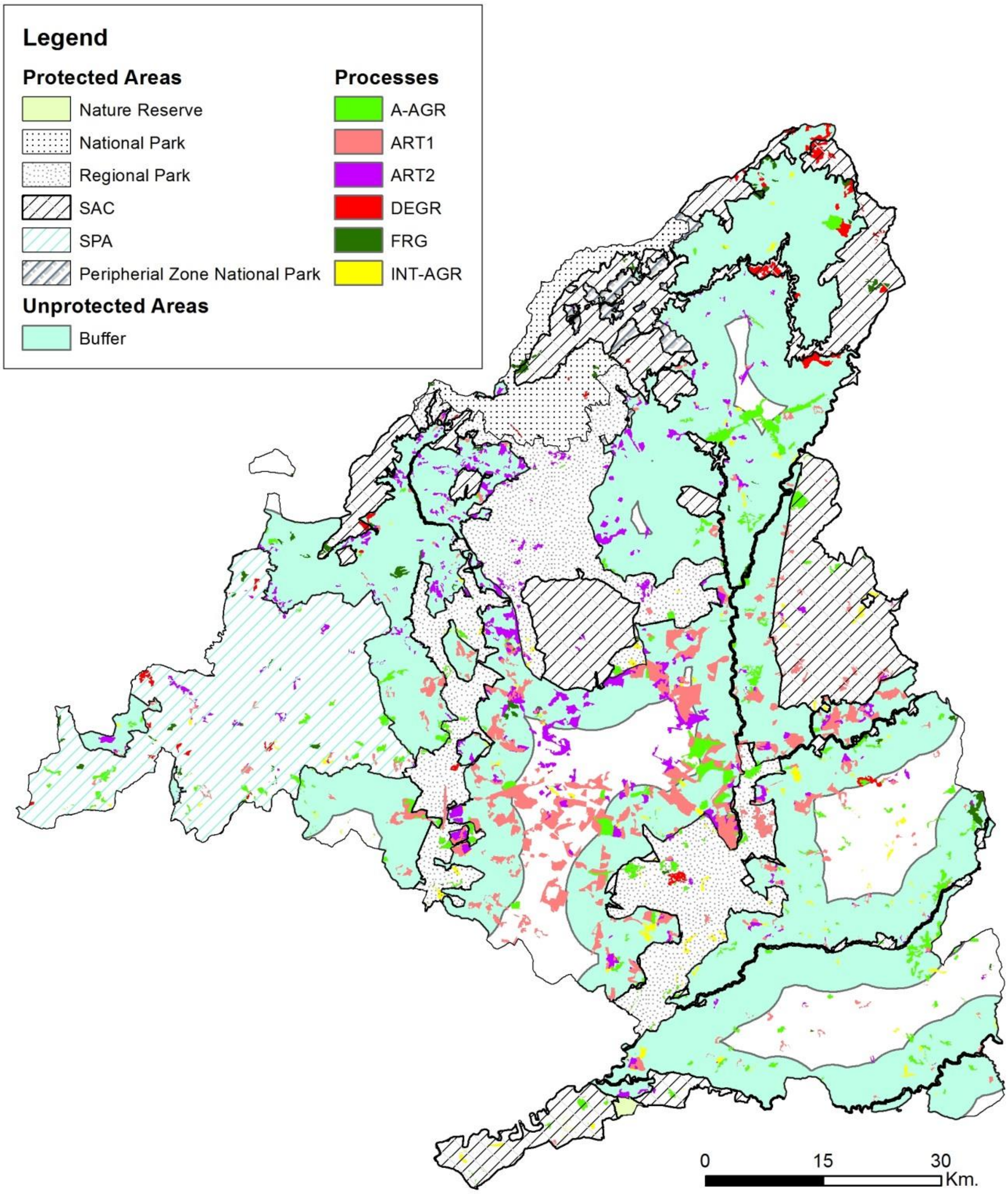

Figure 2: Land use change dynamics occurred in the Region of Madrid between 1990 and 2006. Sources: CLC1990, CLC2006 and perimeters of Protected Areas (MAPAMA). Own elaboration.

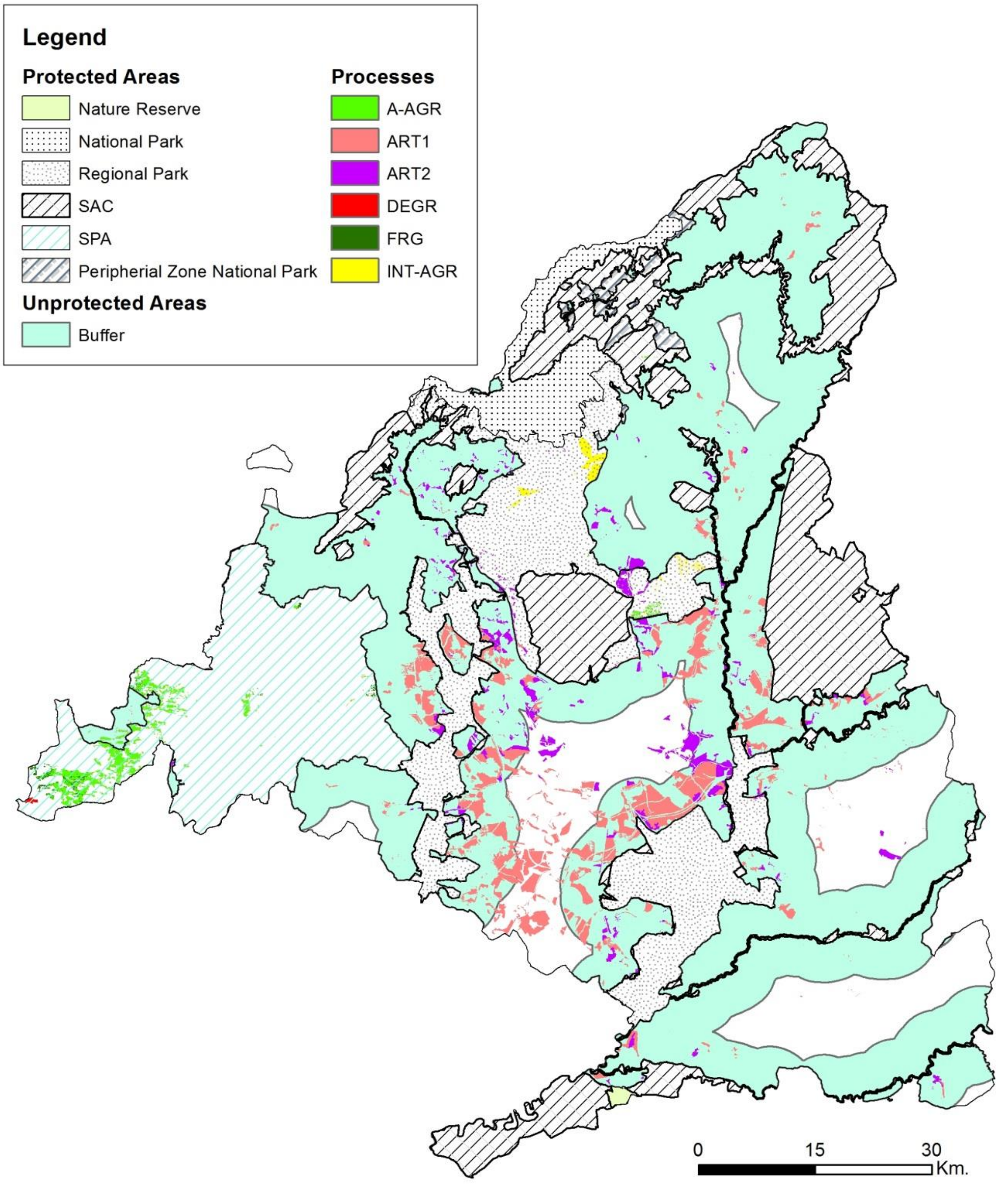

Figure 3: Land use change dynamics expected in the Region of Madrid between 2006 and 2025 under a "business as usual" scenario. Sources: CLC1990, CLC2006, perimeters of Protected Areas (MAPAMA) and other auxiliary geographic data. Own elaboration.

In this area almost 28.000 hectares will be added to the current urban area. The impacts that will generate (soil sealing, biodiversity loss, fragmentation, habitat isolation) are subject of concern for environmental groups and PA managers.

5 DISCUSION OF THE RESULTS

In order to update our study, it would be very useful to have access to CLC2012. However, there has been a change in the elaboration of its methodology, so at the present time CLC2012 can only be compared with CLC2006 version 18.5.

Another topic for discussion is the size of the buffer. A width of 10 km is often used in the literature, (Bruner et al. 2001; Figueroa and Sánchez-Cordero 2008; Martinuzzi et al. 2015). In the case of the region of Madrid, a 10km buffer would be a complex solution because, with the territorial distribution of its PAs, much of the regional surface area would be within that buffer and it would include ecosystems that are very different to those represented in the PAs that were urbanised many decades ago. Other Works, have used a dinamic buffer (1km inside and 1km and 5km outside the PA, Spracklen et al., 2015).

The results obtained in our research are in line with the findings of previous studies on land use change in similar or nearby areas (Ruiz-Benito et al. 2010; Hewitt and Escobar 2011; Díaz-Pacheco and Gutiérrez 2013; Gallardo and Martínez-Vega 2016). They are also in line with the results of future scenarios in protected areas and their surroundings in the region of Madrid (Ruiz-Benito et al. 2010) and in the USA (Martinuzzi et al. 2015).

6 CONCLUSIONS

In general, agricultural areas contributed most to the growth of urban areas. Although in relative terms persistence is very high inside the PAs, the increase in built-up area is a worrying process from an ecological point of view. Naturalisation of abandoned agricultural land is less worrying from the ecological and surface area points of view. Revegetation affected over 10,000 ha, about 3% of the area studied. Both processes occurred with greater intensity in the areas around the PAs.

In urban areas such as the Madrid region the spill-over effect of protected areas should be monitored. It is clear that they attract urban developments to less protected areas around them. Transformation of their agricultural and natural habitats may have irreversible effects on biodiversity. Fragmentation brings with it longer exterior and interior edges. It can also create external threats for protected areas such as invasion by exotic species or the propagation of forest fires. These threats increase the potential ecological vulnerability of these spaces.

ACKNOWLEDGEMENTS

This research received funding from the Spanish National R&D project ‘‘DISESGLOB: Design of a Methodology for Monitoring and Assessing the Overall Sustainability of National Parks and the Influence of Expected Changes of Use” (CSO2013-42421-P). Marta Gallardo was sponsored by a JAE-Predoc Grant from the Spanish National Research Council (CSIC).

REFERENCES

Améztegui A, Brotons L, Coll L. 2010. Land-use changes as major drivers of mountain pine (Pinus uncinata Ram.) expansion in the Pyrenees. *Glob Ecol Biogeogr* 19(5):632-641. doi:10.1111/j.1466-8238.2010.00550.x

Bruner AG, Gullison RE, Rice RE, da Fonseca GAB. 2001. Effectiveness of Parks in Protecting Tropical *Biodiversity. Science* 291: 125-128

Chuvieco E, Martínez S, Román MV, Hantson S, Pettinari L. 2013. Integration of ecological and socio-economic factors to assess global vulnerability to wildfire. Glob *Ecol Biogeogr* 23(2):245-258. doi:10.1111/geb.12095

Dantas de Paula M, Groeneveld J, Huth A. 2015. Tropical forest degradation and recovery in fragmented landscapes. Simulating changes in tree community, forest hidrology and carbon balance. *Global Ecology and Conservation* 3:664–677. doi:10.1016/j.gecco.2015.03.004

Díaz-Pacheco, Gutiérrez J. 2013. Exploring the limitations of CORINE Land Cover for monitoring urban land-use dynamics in metropolitan areas. *Journal of Land Use Science*. doi:10.1080/1747423X.2012.761736

Eastman JR. 2012. *IDRISI Selva. Guía para SIG y procesamiento de imágenes*. Clark University, Worcester

Figueroa F, Sánchez-Cordero, V. 2008. Effectiveness of natural protected areas to prevent land use and land cover change in Mexico. *Biodivers Conserv* 17:3223–3240. doi:10.1007/s10531-008-9423-3

FRA. 2010. *Global Forest Resources Assessment 2010*. FAO, Rome. http://www.fao.org/docrep/013/i1757e/i1757e.pdf. Accessed 22 January 2017

Gallardo M. 2014. *Cambios de usos del suelo y simulación de escenarios en la Comunidad de Madrid (Changes in land use and simulation scenarios in the region of Madrid)*. Universidad Complutense, Madrid http://eprints.ucm.es/25253/. Accessed January 2017

Gallardo M, Martínez-Vega J. 2016. Three decades of land-use changes in the region of Madrid and how they relate to territorial planning. *Eur Plan Stud* 24(5): 1016-1033 doi.10.1080/09654313.2016.1139059

Hewitt R, Escobar, F. 2011. The territorial dynamics of fast-growing regions: Unsustainable land use change and future policy challenges in Madrid, Spain. *Appl Geogr* 31(2):650–667. doi:10.1016/j.apgeog.2010.11.00

Hewitt, R., Pera, F. and Escobar, F. 2016. Cambios recientes en la ocupación del suelo de los parques nacionales españoles y su entorno. *Cuadernos Geográficos* 55(2), 46-84.

Juffe-Bignoli *D,* Burgess ND, Bingham H, Belle EMS, de Lima MG, Deguignet M, Bertzky B, Milam AN, Martinez-Lopez J, Lewis E, Eassom A, Wicander S, Geldmann J, van Soesbergen A, Arnell AP, O'Connor B, Park S, Shi YN, Danks FS, MacSharry B, Kingston N. 2014. *Protected Planet Report 2014*. UNEP-WCMC, Cambridge https://portals.iucn.org/library/sites/library/files/documents/2014-043.pdf. Accessed 22 January 2017

Lambin EF, Turner BLI, Geist HJ, Agbola SB, Angelsen A, Bruce JW, Coomes OT, Dirzo R, Fischer G, Folke C, George PS, Homewood K, Imbernon J, Leemans R, Li X, Moran EF, Mortimore M, Ramakrishnan PS, Richards JF, Skänes H, Steffen W, Stone GD, Svedin U, Veldkamp TA, Vogel C, Xu J. 2001. The causes of land-use and land-cover change: moving beyond the myths. *Glob Environ Change* 11:261–269. doi:10.1016/S0959-3780(01)00007-3

Lei C, Lin Z, Zhang Q. 2014. The spreading front of invasive species in favorable habitat or unfavorable habitat. *Journal of Differential Equations* 257:145-166. doi:10.1016/j.jde.2014.03.015

López Lambas ME, Ricci S. 2014. Planning and management of mobility in natural protected areas. *Procedia Soc Behav* Sci 162:320-329. doi:10.1016/j.sbspro.2014.12.213

Martínez-Fernández J, Ruiz-Benito P, Zavala MA. 2015. Recent land cover changes in Spain across biogeographical regions and protection levels: Implications for conservation policies. *Land Use Policy* 44:62-75. doi:10.1016/j.landusepol.2014.11.021

Martinuzzi S, Radeloff VC, Joppa LN, Hamilton CM, Helmers DP, Plantinga AJ, Lewis DJ. 2015. Scenarios of future land use change around United States' protected areas. *Biol Conserv* 184:446-455. doi:10.1016/j.biocon.2015.02.015

McDonald RI. 2013. Implications of Urbanization for Conservation and Biodiversity Protection. In: Levin SA (ed.) *Encyclopedia of Biodiversity*, 2nd edn. Academic Press, Amsterdam, p 231–244

Moreira F, Rego FC, Ferreira PG. 2001. Temporal (1958–1995) pattern of change in a cultural landscape of northwestern Portugal: implications for fire occurrence. *Landscape Ecology* 16(6): 557-567

Pontius Jr RG. 2000. Quantification error versus location error in comparison of categorical maps. *Photogramm Eng and Remote Sens* 66:1011-1016.

Romero-Calcerrada R, Perry GLW. 2004. The role of land abandonment in landscape dynamics in the SPA Encinares del rio Alberche y Cofio, Central Spain, 1984–1999. *Landsc Urban Plan* 66:217–232. doi:10.1016/S0169-2046(03)00112-9

Ruiz Benito P, Cuevas JA, Bravo de la Parra R, Prieto F, García del Barrio JM, Zavala MA. 2010. Land use change in a Mediterranean metropolitan region and its periphery: assessment of conservation policies through CORINE land cover data and Markov models. *For Syst* 13(3):315–328

Ruiz-Mallén I, Corbera E, Calvo-Boyero D, Reyes-García D. 2015. Participatory scenarios to explore local adaptation to global change in biosphere reserves: Experiences from Bolivia and Mexico. *Environ Sci Policy* 54:398-408. doi:10.1016/j.envsci.2015.07.027

Sastre P, Lucio JV, Martínez V. 2002. Modelos de conectividad del paisaje a distintas escalas. Ejemplos de aplicación en la Comunidad de Madrid. *Ecosistemas* 11(2). Accessed 22 January 2017

Sangermano F, Toledano J, Eastman JR. 2012. Land cover change in the Bolivian Amazon and its implications for REDD+ and endemic biodiversity. *Landsc Ecol* 27:571–584. doi:10.1007/s10980-012-9710-y

Spracklen BD, Kalamandeen M, Galbraith D, Gloor E, Spracklen DV. 2015. A global analysis of deforestation in moist tropical forest Protected Areas. *PlosOne* 10(12): e0143886. doi:10.1371/journal.pone.0143886

Van Vliet J. 2009. Assessing the accuracy of changes in spatial explicit land use change models. In: *12th AGILE International Conference on Geographic Information Science*, Leibniz Universität, Hannover, 2-5 June 2009

Viedma O, Moity N, Moreno JM. 2015. Changes in landscape fire-hazard during the second half of the 20th century: Agriculture abandonment and the changing role of driving factors. *Agric Ecosyst Environ* 207:126-140. doi:10.1016/j.agee.2015.04.011