Chapter 10

Cartography of Landscape Dynamics in Central Spain

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/47841

1. Introduction

Ecological and spatial analysis helps us to characterize the territory and know the spatio-temporal relationship between different components of the landscape. Landscape ecology has developed several methods of assessment and analysis of indicators by using Geographical Information Systems [1-4]. Such methods allow characterization of changes in land structure and land uses, as well as the interpretation of the ecological consequences of these dynamics [5]. They also facilitate analysis of the territory, trying to recognize and compare different spatial configurations, using patches of different shapes, numbers, classes, etc. [6-8].

Several authors have carried out research attempting to integrate the study of territorial dynamics, from an ecological perspective, using Geographic Information Systems [9, 10]. The landscape is influenced by natural and anthropic processes, and the effects of both factors are expressed either at local or regional scale on the territory, showing changes in their structure and composition [11]. Clearly, the landscape appears to us as a complex of many different elements that can reach a great diversity [12]. In Mediterranean areas, the landscape is characterized by a heterogeneous mosaic of land uses and vegetation, where natural subsystems coexist adjacent to other systems at different degrees of perturbation due to human intervention and, therefore, with different degree of ecological maturity, separated by clear boundaries [13, 14]. The intense dynamic of land use changes occurred in these areas over recent decades has caused important changes in the structure of the landscape, as a result of fragmentation processes [14-19]. This influences various ecological processes, including those relating to the matter and energy flows between patches, by altering the composition and distribution of communities, the survival and coexistence of species, and species diversity [20-25].

The region of Madrid, due to its geographical location (centre of the Iberian Peninsula), and physiographic variability, -from the Cordillera Central to the river Tagus depression-, has a variety of lithological, mesoclimatic, edaphic and geomorphological traits, which have resulted in a great diversity of ecosystems, land use types and landscapes, some of them of great natural value. For example, It is noteworthy the contrast between areas of the Guadarrama Range (belonging to the Central Mountain Ranges), where summits and slopes covered by pine and oak forests, dehesas and grasslands of high nature value, are well-preserved, compared to other areas intensely humanized, that have a very deteriorated landscape, such as the metropolitan area of Madrid. In the recent history of this region there is a clear abandonment of traditional agricultural activities that had provide the maintenance of semi-natural systems with a high degree of functionality, which has resulted in a clear instability [26]. Thus, at present, there is a heavily modified landscape, more homogeneous and probably more polluted, that has lost much of the typical positive externalities of the traditional landscape (natural services, basic ecological processes, biodiversity, aesthetic tourist-recreational values, etc).

For this reason, much of the territory of Madrid Region is protected by European Community legislation, as well as national and regional laws, which aim to consolidate the protection and conservation of natural diversity, and at the same time, seek to promote (uphold, improve) sustainable development.

Since 1985, the autonomous government of Madrid has declared seven protected areas, which represent 14% of its surface, so it is the sixth region in Spain in terms of protected territory. In parallel, along decades, there has been a very important socio-economic development in the region, a great population growth and a deep process of change in the use and exploitation of the area's resources. This study was conducted in a Protected Natural Ares stated at 1985.

The aims of this study were, firstly, to analyse the main changes in land use occurred inside the Protected Natural Area (PNA) over a period of 35 years, in order to determine the principal territorial dynamics occurred, and the consequences of these processes of change on the landscape configuration and on the evolutions of territorial structure in this PNA. Secondly, in a smaller geographical context, GIS tools are combined with key ecological parameters such as richness of uses, diversity (by Shannon) [27], evenness, connectivity and fragmentation, to analyze the structure and organization of the territory.

2. Study area

We conducted our study in the PNA (Cuenca Alta del río Manzanares), located quite close to Madrid city (approximately 50 km NW, Figures 1 and 2). This PNA is characterised by a mid-mountain Mediterranean landscape, with altitudes ranging from 660 m to 2,200 m. The summits with slopes of gneiss and granite are covered by oak (*Quercus pyrenaica*) and pine reforestation (*Pinus sylvestris*). On these slopes is located one of the most important granite landscapes of Europe, "La Pedriza", protected since 1930. A rocky piedmont covered by "dehesas" of *Quercus ilex* subsp. *ballota* links to the sedimentary river Tagus basin, where alternate cereal crops with oak forests. The Spanish Committee of UNESCO's MAB

Programme in 1992 designated the area as a Biosphere Reserve, due to the high ecological value of the area as well as for its cultural heritage and agricultural and landscape values.

Demography, recreation and urban and transport infrastructures development are the most important pressures in this PNA [28]. This Park was declared a PNA in 1985 abarcando una extensión de casi 53.000 ha [29]. Biogeographically, this territory belongs to the Mediterranean Iberian-Atlantic region in the Central Mountain Range.

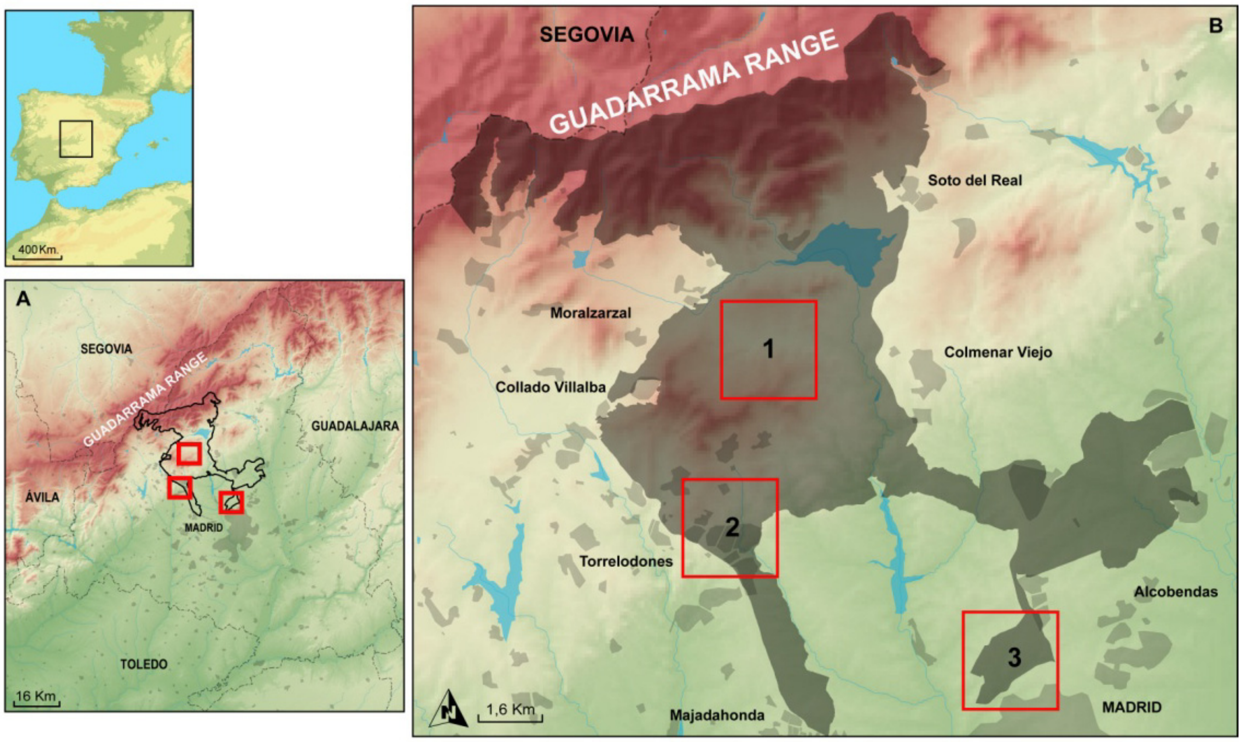

Figure 1. Study area: Location in Madrid region (A) and the location of the three study cases (B): Cerceda (1), Torrelodones (2). Fuencarral (3) into boundary of PNA (shadow).

Figure 2. Guadarrama Range and piedmont with open woodland and urban development in PNA (Cuenca Alta del Río Manzanares)

3. Methodology

We used cartographic techniques that combine remote sensing and GIS, with ecological analysis at different spatial scales. Both methods allowed us to determine the landscape changes and to detect pressures acting upon some areas included in the PNA during the last decades (urban and transport infrastructures development, etc). We reviewed i) previous studies focused on photo-interpretation techniques [30-34]; ii) land uses changes and territorial dynamics in different environmental conditions [35-40] and iii) definition of land uses categories [41-44]. We chose two working scales: the first analyzed the variability of the PNA as a whole (1:50,000), and the second, that use a more detail scale, permited us to recognize different ecological processes that occurred in the territory (1:12,500).

We used the aerial photography of Spanish Air Force of 1975 and the orthophotography of 2009 (Plan Nacional de Ortofotografía Aérea). ERDAS Imagine 9.1 software was used for processing analogical information (1975 flight, Spanish Air Force). Previously, we had tested ER-MAPPER and ArcGis 9.10 methods to this end. We scanned each of 150 photograms at 600 dpi. Mosaicing was conducted using Mosaic Tool extension. This tool showed the best balanced colour result. Each photo was improved with a Root Mean Square (RMS) and its tolerance was less than 0.5. Distortions of the photos were corrected using a Digital Terrain Model (DTM) at 1:5,000 scale. Re-sampling method applied was the nearest neighbour algorithm employing at least a cubic polynomial fit using 15 Control Ground Points and at least 10% of overlapping areas. The result was a continuous image of the study area with a 5 x 5 m resolution.

Phenological changes mean different colours that depend on season and this colour difference causes errors in the photo-interpretation so, it was necessary to balance colours for the ortophotography of 2009 (2.5 x 2.5 m resolution).. This problem is more evident in agricultural areas. Likewise, existing vegetation and land use maps of Madrid Region were reviewed [45, 46]. All layers were managed in a format compatible with ArcGIS 9.3 (shapefile, coverage or GRID) referred to the WGS84 ellipsoid and UTM coordinates Zone 30 N.

The photo-interpretation considered an accuracy of the reference map unit depending on the type of area, establishing a minimum of 0.5 ha (1:12,500 scale), similar to that used in other studies with this orthophotography scale in forest formations [47] and of 0.61 ha (1:50,000 scale) using cartographic techniques that merge patches (dissolve ie.) Also on the orthophotography were required some data about the phytostructure and percentages of canopy cover. If necessary, we worked with DGPS techniques (GPS Trimble Nomad 6GB) to refine the patches shape.

We employed a touch screen Wacom Cintig 12WX joined to ArcGis editor. Topological errors were processed using ARCEDIT. Finally, we assigned a topology to each layer using ARC/INFO 9.1. Database was designed with three fields: land use, connectivity value and surface area (ha).

The photointerpretation was completed with fieldwork. It took over 2,000 panoramic photographs for checking on field the areas that were more complex during the development of cartography. It was considered of interest to note the state or degree of consolidation of urban or under urban development, as this is one aspect that has changed in the whole Madrid Region from the 70's of last century.

We then crossed the two land-use maps by means of techniques of overlapping and digital layer intersection, thus comparing the information from both years. The result was a new map on which each patch showed the land use observed in both years. Thus, we identified all the types of changes that had taken place in the PNA during the 35-year period. Then it was possible to know if each type of vegetation or land use in each part of the territory has changed or not. Results allowed us to identify a set of changes occurred in the PNA during these 35 years.

Then we calculated the percentage of the area that has changed in the whole PNA and for each type of dynamic [28, 48]. These percentages allowed us to establish categories of dynamism that distinguished zones of more or less changing and map its spatial distribution. Finally, we used categories of dynamism map (1:12,500 scale) to select three locations. We conducted a more detailed study about natural dynamic of territory [49-51], using a set of ecological parameters as indicators of structure and organization of territory.

A more detailed study allowed us to recognize and map 23 types of land uses. These were the result of consider at the same time land uses and vegetation units. Using this criterion we obtained categories as Dehesas *of Quercus ilex* subsp. *ballota* i.e.

In each selected locations, we calculated relative frequencies of each land use type using their abundance, and graphed their relative frequency profile in 1975 and 2009. Each profile has been defined by three parameters: the richness of land uses, R(u), calculated as the number of different categories of land uses in the corresponding year [52]; Shannon's diversity, H'(u), expressed in bits [27]; and Pielou's evenness, E(u) [53].

Evenness is the proportion between observed diversity value and maximum diversity value that would be possible to reach with the registered R(u). High values of E(u) indicate an even land use distribution, that means that there are not a dominating land use in the territory. To the contrary, low values of E(u) are indicating that one or a small set of land uses are more frequent [54].

In order to complete the study of evolution of territorial structure and organization, we analyzed ecological connectivity and fragmentation in each selected location in 1975 and 2009.

We calculated ecological connectivity (c) of territory according to a set of permeability values assigned to each land uses. These permeability values were established taking into account matter and energy flows (genes, seeds, species, etc.) through two adjacent land uses [55-57], and assessing the quality of each land uses according to landscape functionality, forestry value, cultural value, among others.

Finally, we calculated fragmentation of territory (f) according to the variation in patches number occurred between 1975 and 2009 at each selected locations. We focused on boundary effect caused by human land uses. Results were mapped.

4. Results

4.1. Diachronic analysis of land uses in a protected natural area

We obtained two diachronic maps showing different scenarios relating to land uses in this territory for 1975 and for 2009, differentiating 7 types (Table 1, Figure 3).

Land uses	Description
Forest	All formations of deciduous leafy tree species primarily *Quercus pyrenaica*
	All formations of sclerophyllous tree species primarily *Quercus ilex* subsp. *ballota*
	Pinus sylvestris forests
Scrub	High altitude shrubland (*Cytisus oromediterraneus)*
	Scrubland with *Cistus ladanifer*, *Lavandula stoechas* subsp. *stoechas*, *Thymus* spp. *Retama sphaerocarpa*
	Scrub with scattered *Quercus ilex* subsp. *ballota* or *Quercus pyrenaica*
Pastures	High-altitude pastures of *Festuca curvifolia*
	Pastures for extensive livestock farming
	Therophytic pastures in abandoned agricultural areas (wasteland)
	Pastures with scrub and scattered trees
Croplands	Dry farming crops
	Irrigated crops
Rocky areas with scrub and trees	Granite landscapes covered by scrubs and trees (*Quercus ilex* subsp. *ballota*, *Pinus sylvestris*,*Juniperus oxycedrus* subsp. *oxycedrus*).
Reservoirs	
Urban areas	Areas under urban development
	Consolidated urban areas

Table 1. Classification and description of the seven land uses and vegetation types in the PNA.

In both years, the most abundant type of land use is pasture, which reflects the importance of extensive livestock farming in this area. Nature conservation in Spain should involve protection and conservation of these traditional agrosilvopastoral systems [58, 59]. An essential ecological feature of this kind of system involves a high level of efficiency in energy and nutrient use. As a result, the use of land resources is optimized and the rural activities are adapted to natural production cycles [60, 61]. The next most abundant types of land use by extension are forest, scrub and rocky areas with scrub and trees. These are all characteristics of this PNA, although the latter comprises this territory's unique landscape. We found no noteworthy changes in number of land uses or in the typology within the protected area. We can only highlight the absence in 2009 of areas under urban development as those identified in 1975 have now become consolidated urban areas (Figure 3). The land uses showing the biggest increase in extension are scrub, tree formations and urban areas, whereas croplands show a decrease.

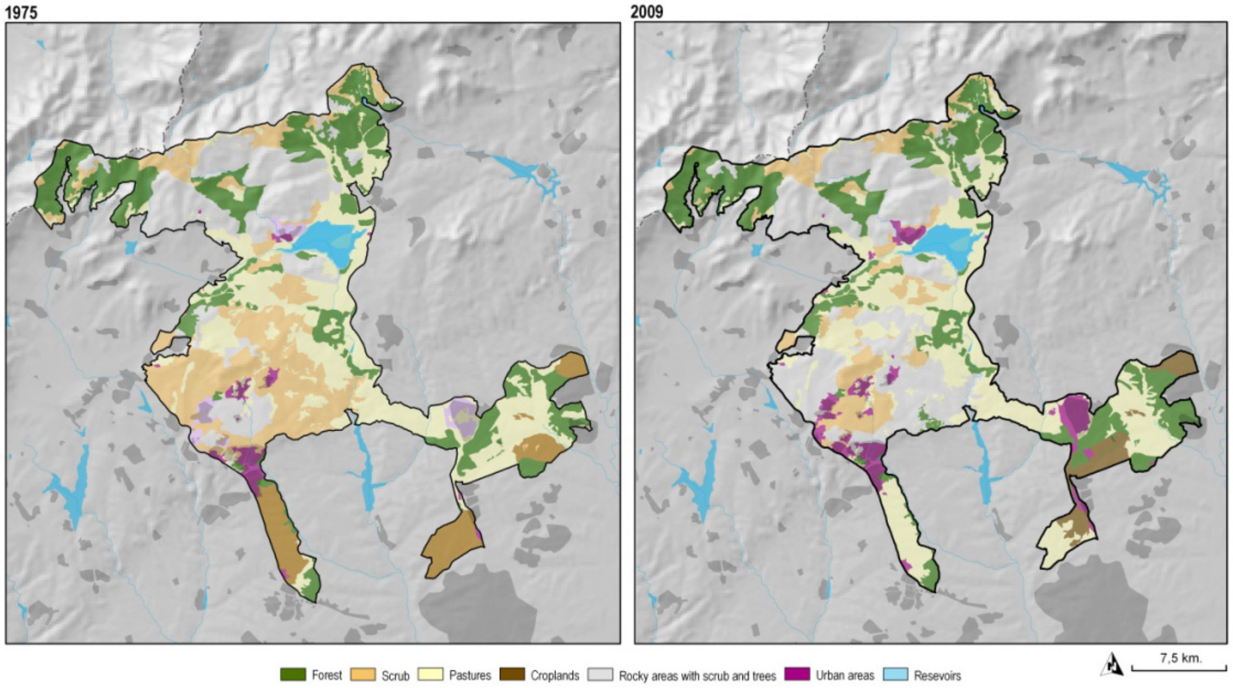

Figure 3. Land uses cartography (PNA)

Land use	1975			2009		
	Ha	% PNA	% Land use	Ha	% PNA	% Land use
Forest	11,326.8	21.4	45.0	12,306.1	23.2	47.1
Scrub	10,427.6	19.7	72.4	11,939.5	22.5	75.6
Pastures	15,185.9	28.7	50.2	15,157.0	28.6	54.4
Croplands	3,587.3	6.8	50.3	1,769.4	3.3	37.5
Rocky areas with scrub and trees	9,329.1	17.6	89.1	8,110.6	15.3	88.1
Reservoirs	1,017.5	1.9	88.7	10,17.5	1.9	88.7
Urban*	1,983.7	3.7	22.6	2,638.8	4.9	21.0

* Includes urban areas and areas under urban development

Table 2. Land uses in 1975 and 2009

4.2. Dynamics and changes in a PeriUrban Park

The comparative analysis of the vegetation and land use maps enabled us to identify and quantify five main change dynamics in the territory: urban development, scrub encroachment, forest encroachment, agricultural abandonment and new crops. Most of these dynamics were consequence of the abandonment of traditional activities or the increase in urbanised areas (Figure 4 and Table 3).

We observed few changes in the study area, indeed, 79.5% of the Park's territory had undergone no change. The total area affected by some type of change from 1975 to 2009 is 10,852.7 ha. Within this changing area, the most significant dynamics were new pastures (29.8%) and forest encroachment (26.6%). Scrub encroachment represents 19.5% and urban development processes 15.7%. New crops represent only 8.8% and occur in the southern sector of the Park (Table 4).

		2009						
		Forest	**Scrub**	**Pastures**	**Croplands**	**Rocky areas with scrub and trees**	**Reservoirs**	**Urban**
1975	**Forest**	NCh	SE*	AA				URB
	Scrub	FE	NCh	AA				URB
	Pastures	FE	SE	NCh	NC			URB
	Croplands	FE		AA	NCh			URB
	Rocky areas with scrub and trees	FE	SE			NCh		URB
	Reservoirs		SE				NCh	URB
	Urban							NCh

* This case is referred to forest cleared for livestock farming, a traditional use in Mediterranean areas.

Table 3. Territorial dynamics from 1975 to 2009. FE: Forest Encroachment; SE: Scrub Encroachment; AA: Agricultural Abandonment; NC: New Crops; URB: Urban Development; NCh: No Change.

		ha	**% PNA**	**% change**	**% dynamics**
DYNAMICS	**FE**	2,884.1	5.4	26.6	3.0
	SE	2,076.7	3.9	19.5	2.1
	AA	3,235.9	6.1	29.8	3.3
	NC	955.1	1.8	8.8	1.0
	URB	1,700.9	3.2	15.7	1.7
	NCh	42,081.8	79.5		43.1

Table 4. Total surface of each dynamic and percentage area over PNA, change and dynamics areas

These dynamics clearly showed the most dynamic sectors (mainly associated with urban development) that are located in the South of the PNA, close to the city of Madrid and to the main communications networks In contrast, the mountainous area located at North presented fewer changes which are associated with natural dynamics (forest and scrub encroachment).

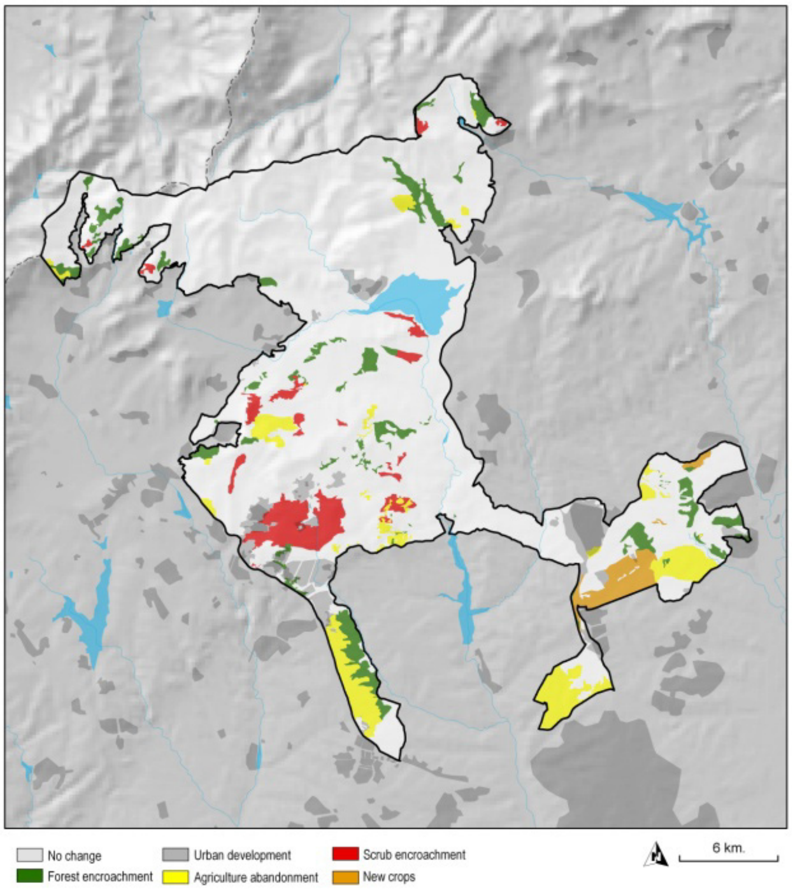

Figure 4. Change dynamics detected in the PNA

		ha	% PNA	% change	% dynamics
DYNAMICS	**FE**	2,884.1	5.4	26.6	3.0
	SE	2,076.7	3.9	19.5	2.1
	AA	3,235.9	6.1	29.8	3.3
	NC	955.1	1.8	8.8	1.0
	URB	1,700.9	3.2	15.7	1.7
	NCh	42,081.8	79.5		43.1

Table 5. Total surface of each dynamic and percentage area over PNA, change and dynamics areas

Percentage area of these types of dynamics in the PNA allowed us to establish four categories or degrees of change: very dynamic (ratio change > 60%); dynamic (ratio change 20-60%); stable (ratio change 12-20%); very stable areas (ratio change <12%) (Figure 5).

The more stables areas were located in the North part of the PNA. Dynamic areas increased from piedmont to Tagus Basin, especially in Madrid and its Metropolitan Area. This has facilitated to select three zones with different land use dynamism (1975-2009). First, a very stable area, named Cerceda that is located on rocky piedmont (over gneisses). The second, Torrelodones, is a transitional area between rocky piedmont and Tagus Basin where urban development is the most significant process (dynamic area). Finally, in the Southeast was located the third, very dynamic area (Fuencarral), over sedimentary materials, with significant changes in agricultural uses (Figure 1 and Figures 5 and 6).

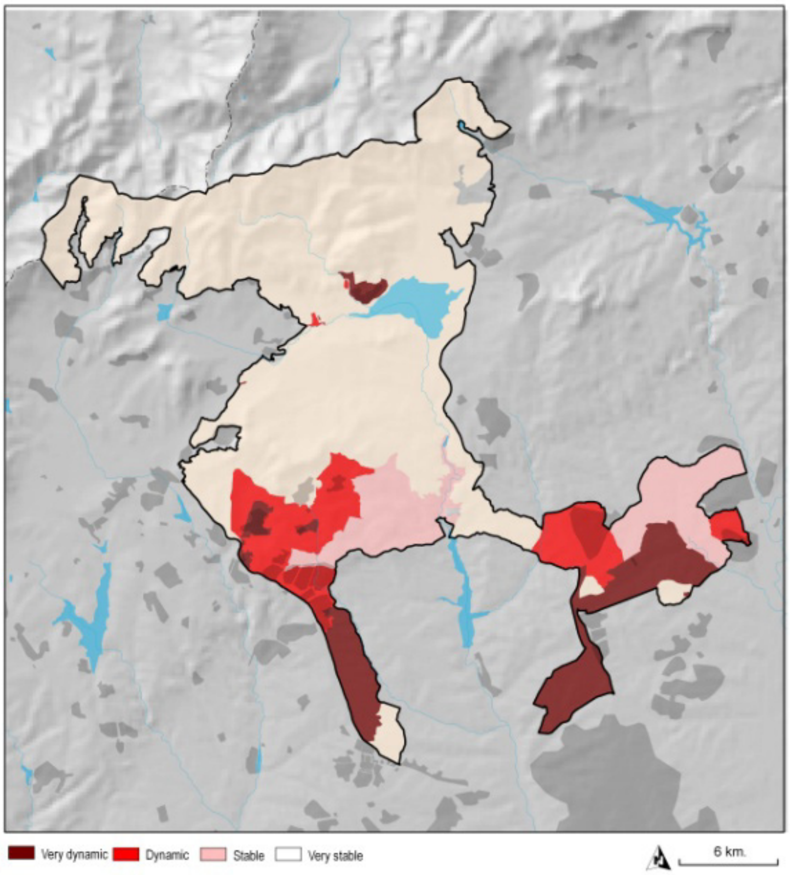

Figure 5. Categories or degrees of dynamism

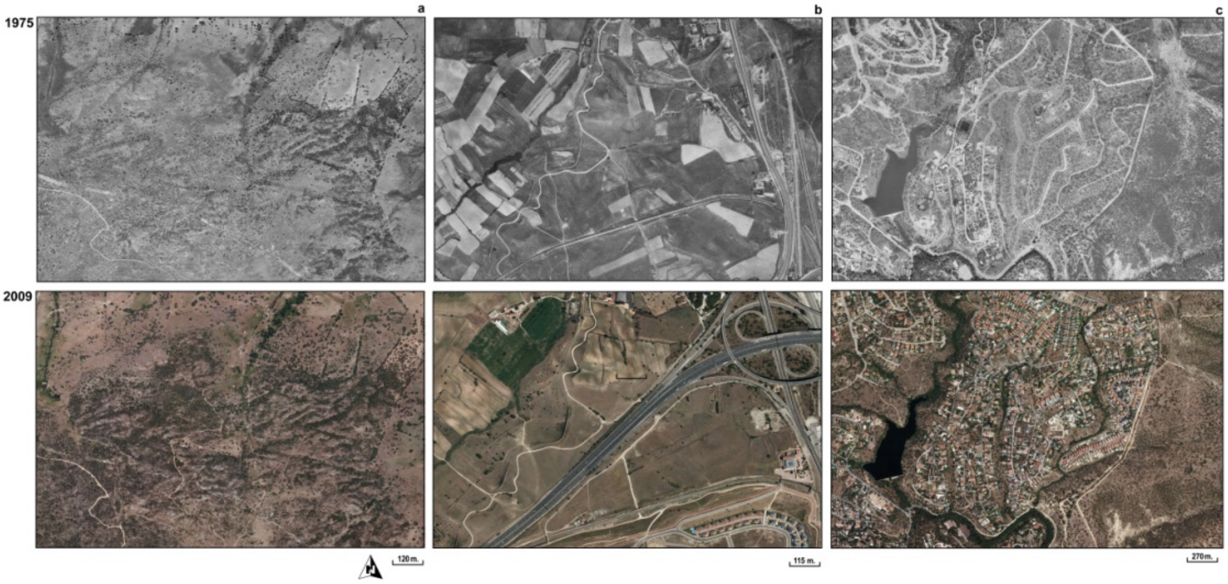

Figure 6. Orthophotographies. Cerceda, scrub encroachment (a); Fuencarral, agricultural abandonment (b); Torrelodones, urban development (c).

4.3. Changes at local scale in three study cases: Shrub encroachment, agricultural abandonment and urban development

As we had mentioned above three areas have been selected for a more detailed analyse (1:12,500 scale). The results obtained are showed below:

4.3.1. Cerceda: Open woodland and shrub encroachment

In Cerceda (Figure 7), there was no difference in R (u) so the number and type of land uses are the same along time. However, there had been some changes in the land use's relative abundance as showed diversity H´(u) and evenness E(u) values (Table 5). The changes in land uses over time have transformed the territory. One of them is dominant, the increase of understory density (Figure 8). These changes in surface are associated to pastures abandonment and the decrease of sheep and goat livestock. Woodland encroachment generated a mixed forest of *Juniperus*, *Quercus* and *Cistus*, with different densities: high density (1975: 15%; 2009: 30%) and medium density (1975: 25%; 2009: 40%). In particular the increase of open woodland areas is associated to intensification with beef cattle or bucking bulls. This intensification is determinant in the phytostructure of medium understory density in open woodland (30%, 1975 / 50%, 2009).

Figure 7. *Juniperus oxycedrus subsp. oxycedrus* and *Quercus ilex* subsp *ballota* open woodlands and farms in Cerceda.

	Cerceda		Fuencarral		Torrelodones	
	1975	**2009**	**1975**	**2009**	**1975**	**2009**
R(u)	10	10	13	13	12	10
H'(u)	2.38	2.25	2.05	2.97	2.81	2.49
E(u)	0.72	0.68	0.55	0.80	0.78	0.75

Table 6. Values of Richness R(u), Diversity H'(u) and Evenness E(u) of land uses in Cerceda, Fuencarral and Torrelodones

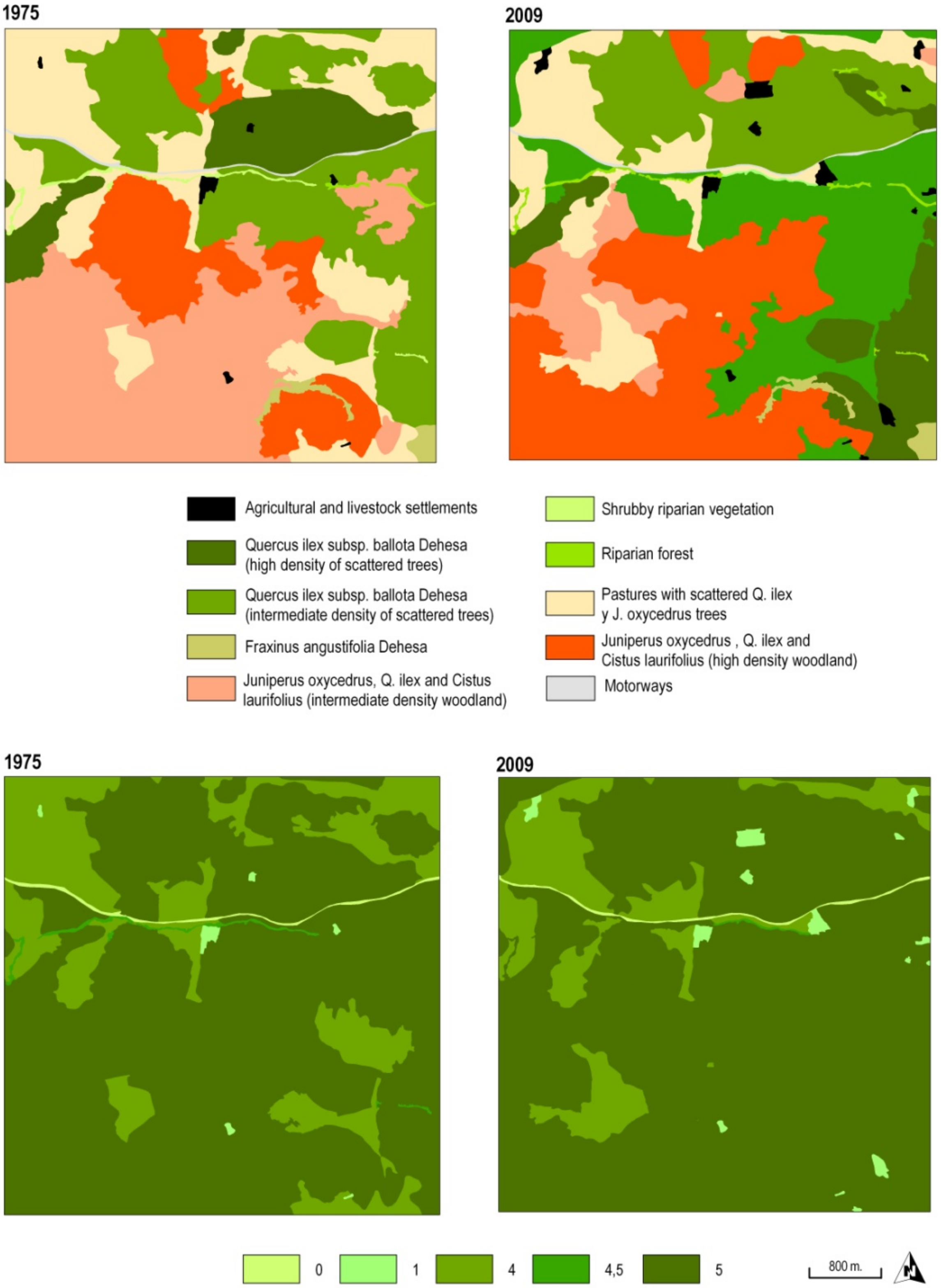

Figure 8. Land uses (1975-2009) and ecological connectivity in Cerceda

Fragmentation measured as total number of patches was significantly higher in 2009 than in 1975. The territory showed no changes and conserved the same permeability in 1975 and in

2009. So the exchange of matter and energy between patches it wasn't modify (Table 6). Finally, territorial connectivity presented the highest values of the three cases. This is an area with few transformations by anthropic uses and that maintains the same vegetation types in both dates (Figure 8).

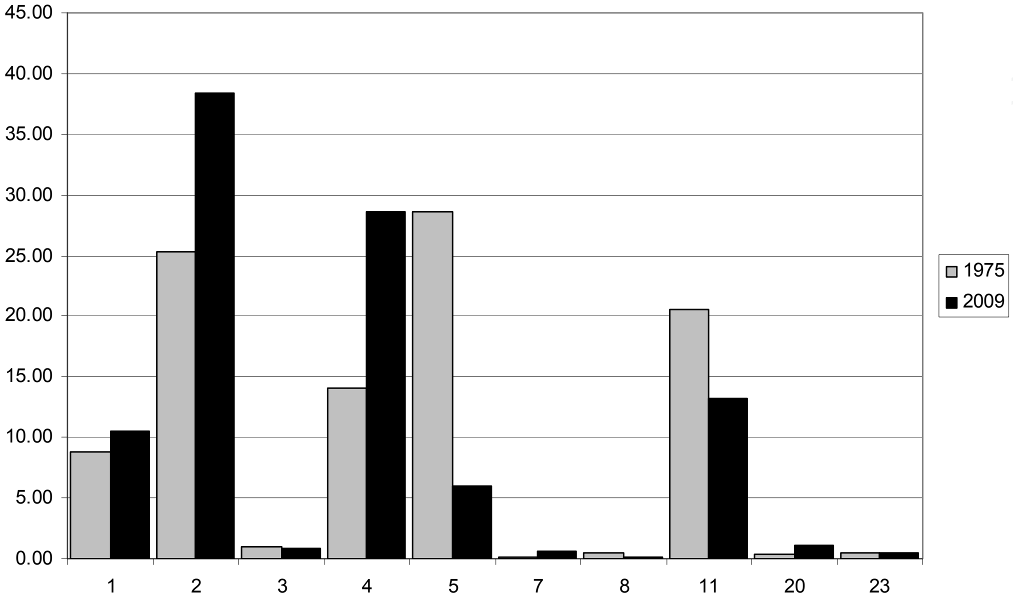

Figure 9. Relative frequency profile of land uses of each year in Cerceda. The codes and the land uses are the same for Table 6

Code	Land use	Number of patches	
		1975	2009
20	Agricultural and livestock settlements	6	13
1	*Q. ilex* subps. *ballota* Dehesa (high density of scattered trees)	4	5
2	*Q. ilex* subps. *ballota* Dehesa (intermediate density of scattered trees)	8	11
3	*Fraxinus angustifolia* Dehesa	2	2
23	Motorways	1	1
4	*Juniperus oxycedrus* subsp. *oxycedrus, Q. ilex* subps. *ballota* and *Cistus laurifolius* (high density woodland)	4	4
5	*Juniperus oxycedrus* subsp. *oxycedrus, Q. ilex* subps. *ballota* and *Cistus laurifolius* (intermediate density woodland)	3	3
11	Pastures with scattered *Q. ilex* subps. *ballota* y *J. oxycedrus* trees	13	11
7	Riparian forest	2	9
8	Shrubby riparian vegetation	7	1
	TOTAL	**56**	**62**

Table 7. Fragmentation value of each land use measured as number of patches in Cerceda. This parameter has been calculated in 1975 and 2009.

4.3.2. Fuencarral: Road infrastructures and urban pressure vs. agricultural abandonment

In the Fuencarral area (Figure 10) still stand the Richness R (u) at both dates (13). The values had certain variations in the H´(u) (1975: 2.05; 2009: 2.97) and E (u) (1975: 0.55; 2009: 0.80). These values showed an increase of landscape heterogeneity. It was also decisive the transformation of an agricultural environment with productive small and medium land parcels in 1975 (Figure 11) in an area characterized for high density of road infrastructures and the abandonment of traditional land uses in 2009 (Figure 12). Furthermore, percentage occupied for wastelands with fruit trees of *Ficus carica, Amygdalus communis* and *Vitis vitifera* and *Triticum/Hordeum* spp. is significant (1975: >50%; 2009: 10%). In 2009 traditional Mediterranean mosaic of land uses disappeared (fruit trees, dry farming crops, wastelands and scrublands) and was replaced by dry farming crops or wastelands with low-productivity. Shrub lands and wastelands had increased their surface area in 2009 especially in wastelands with *Retama sphaerocarpa* (20%) and shrub lands (5%). In many cases is difficult to distinguish between dry farming crops and wastelands on ortophotography. However wasteland's surface took a progressive reduced and transformed in non productive areas. In 2009 riparian forest area increased while in 1975 was fragmented (Table 7).

We analyzed that total patches number has been decreased between 1975 and 2009. Due to agricultural abandonment a homogeneous landscape was generated. Particularly this type of landscape maintains a great diversity of land uses, wastelands and habitats well preserved that have and interesting role such as ecological and territorial connectors [61]. In this area the connectivity at edges has decreased due to increase of road infrastructure and urban development.

Figure 10. Countryside with fruit trees and crops in Fuencarral

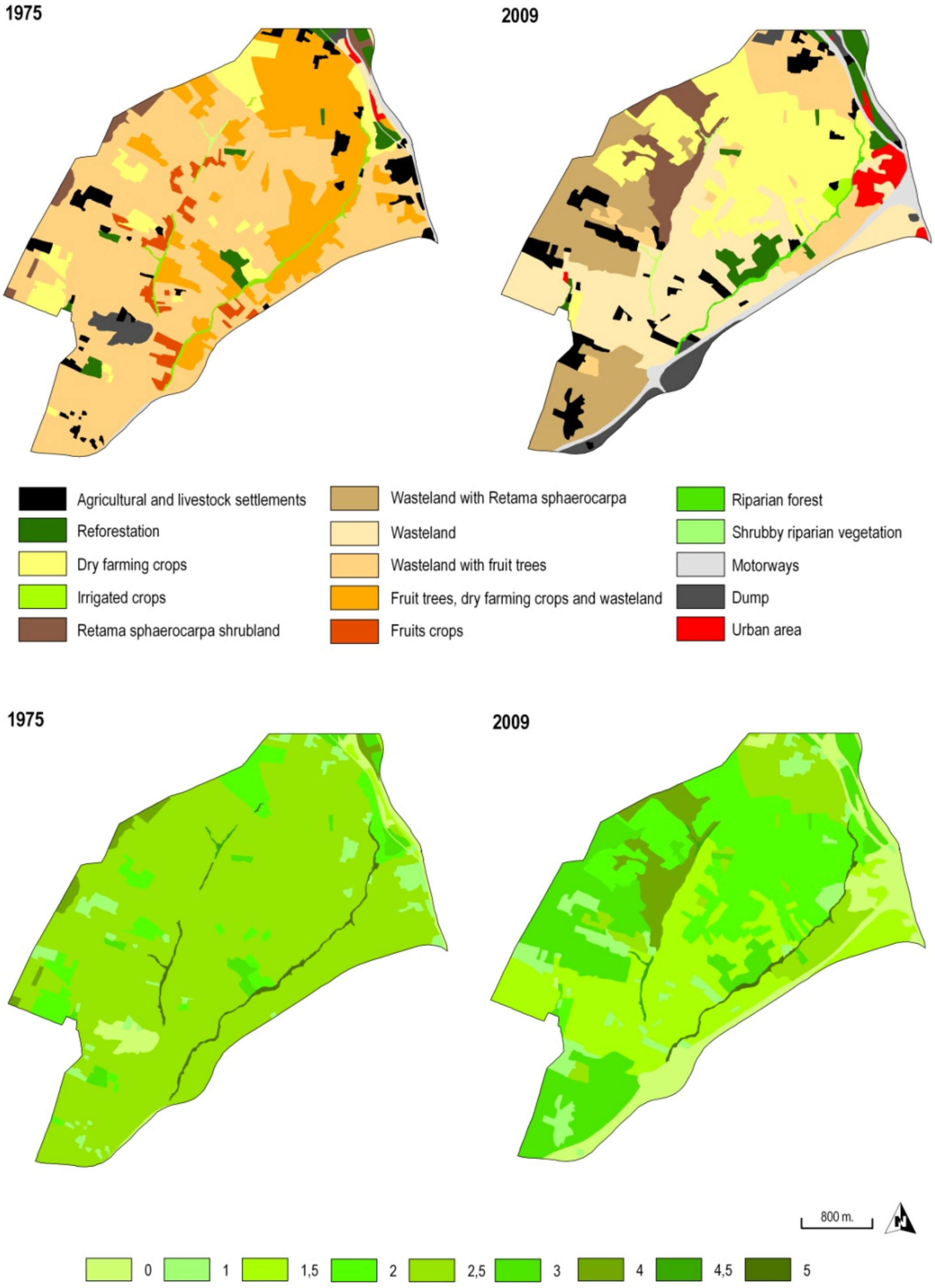

Figure 11. Land uses (1975-2009) and ecological connectivity in Fuencarral

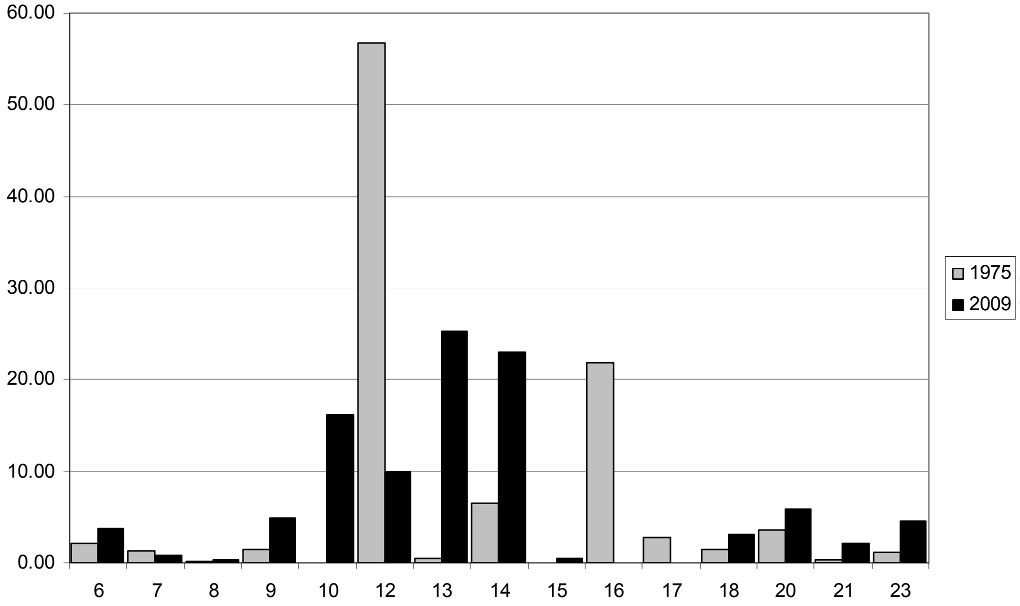

Figure 12. Relative frequency profile of land uses of each year in Fuencarral. The codes and the land uses are the same for Table 7.

Code	Land use	Number of patches	
		1975	**2009**
20	Agricultural and livestock settlements	36	29
15	Irrigated crops	0	1
14	Dry farming crops	13	6
6	Reforestation	14	13
13	Wasteland	3	10
12	Wasteland with fruit trees	5	9
18	Dump	2	8
12	Fruit trees, dry farming crops and wasteland	22	0
17	Fruits crops	15	0
23	Motorways	2	1
9	*Retama sphaerocarpa* shrubland	6	2
10	Wasteland with *Retama sphaerocarpa*	0	3
7	Riparian forest	4	1
8	Shrubby riparian vegetation	1	2
21	Urban area	2	8
	TOTAL	**125**	**96**

Table 8. Fragmentation value of each land use measured as number of patches in Fuencarral. This parameter has been calculated in 1975 and 2009.

4.3.3. Torrelodones: Urban development in a PNA

Urban development was the more significant process in Torrelodones area (Figure 3) The H´(u) values (1975: 2.81; 2009: 2.49) are remarkable and these, added homogeneity to landscape. The R (u) (1975: 12; 2009: 10) and E (u) (1975: 0.78; 2009: 0.75) values were almost unchanged (Table 5 and figure 15). The most important changes (Figure 14) were located in urban areas consolidated between both dates (2009: > 30%; 1975: 15%). The surface of mixture arborescens or shrubby woodlands with high density (*Juniperus*, *Cistus*, *Quercus*) decreased (1975: 20%; 2009: < 10%) and were replacement with urban areas. Into intermediate density woodlands the process is the contrary with a slight increase (2009: 30%). In this example values corresponded to disturbed areas near of urban areas or changes in livestock production (beef cattle into extensive o semi-extensive pastoral system).

As for fragmentation, although patches number decreased in 2009, the territory was more anthropic concentrating such growth in this sector analyzed in conjunction with the boundary of the PNA (Table 8 and Figure 14). This produced a boundary effect preventing the exchange of matter and energy in that direction and causing isolation of the territory whose consequences have been already indicated by several authors: loss of diversity and of species, less permeability, worst energy flow, etc. [62-64]. Such an example it was the large increase of road infrastructures in 2009 more greater than 1975. This is especially significant with N-VI, nowadays a highway that introduced fragmentation and negatives effects over territory (Figure 14). The connectivity of the territory is also affected overtime, showing a loss of permeability that results in a lower exchange of individuals between populations, lower the persistence of local and regional populations, increasing the rate of extinction and reducing the rate of colonization. Landscape connectivity favours not only movements of animal species, but also of plant and material and energy flows [65-67]. Therefore shows a loss of connectivity and increased fragmentation with the passage of time which is located predominantly in the edge of the ENP. This causes a barrier effect in that direction forcing the processes and natural movements to move into the space where connectivity is maintained higher and less fragmentation.

Figure 13. Single-family housing at the western edge of PNA (Torrelodones)

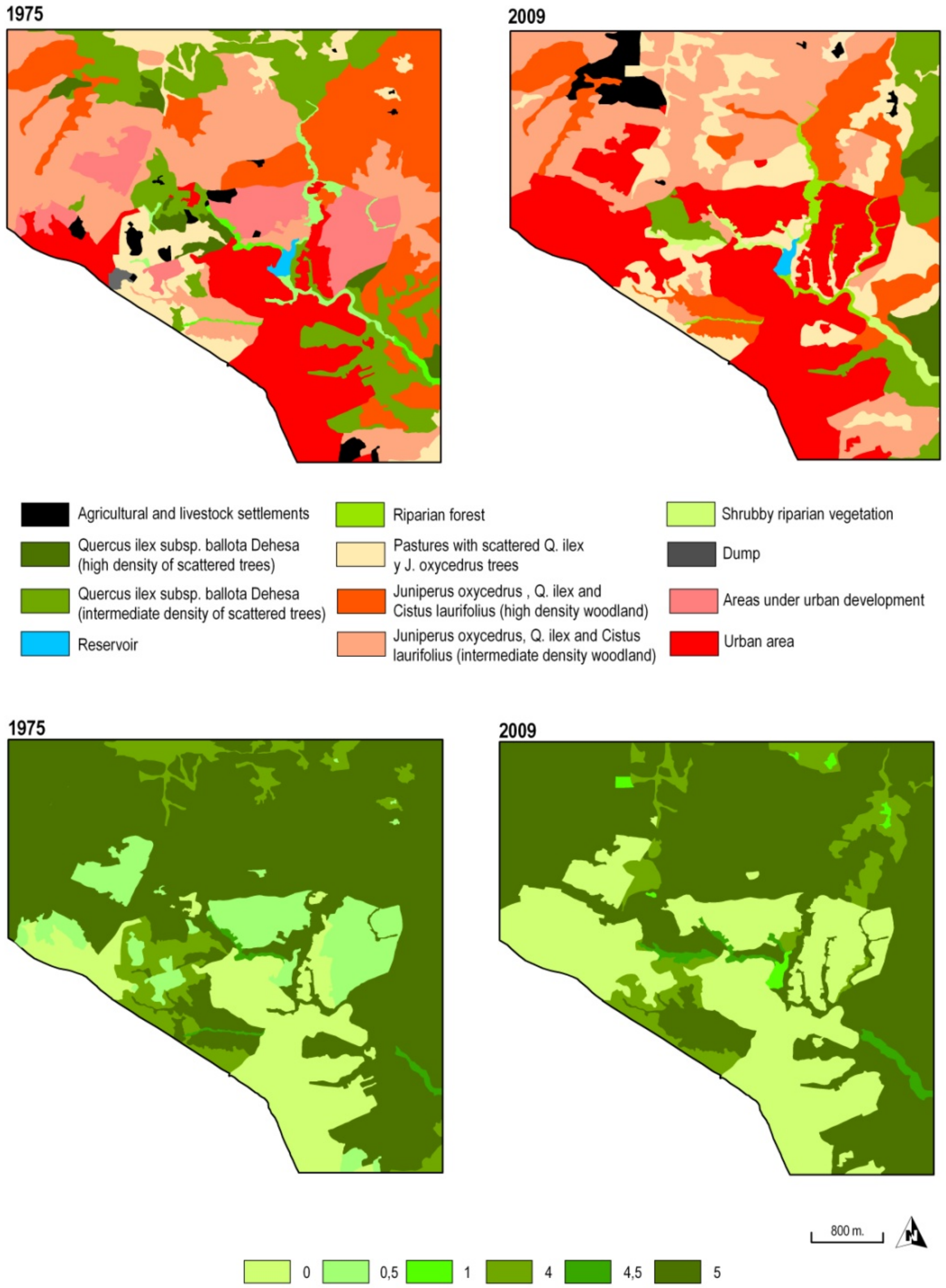

Figure 14. Land uses (1975-2009) and ecological connectivity in Torrelodones

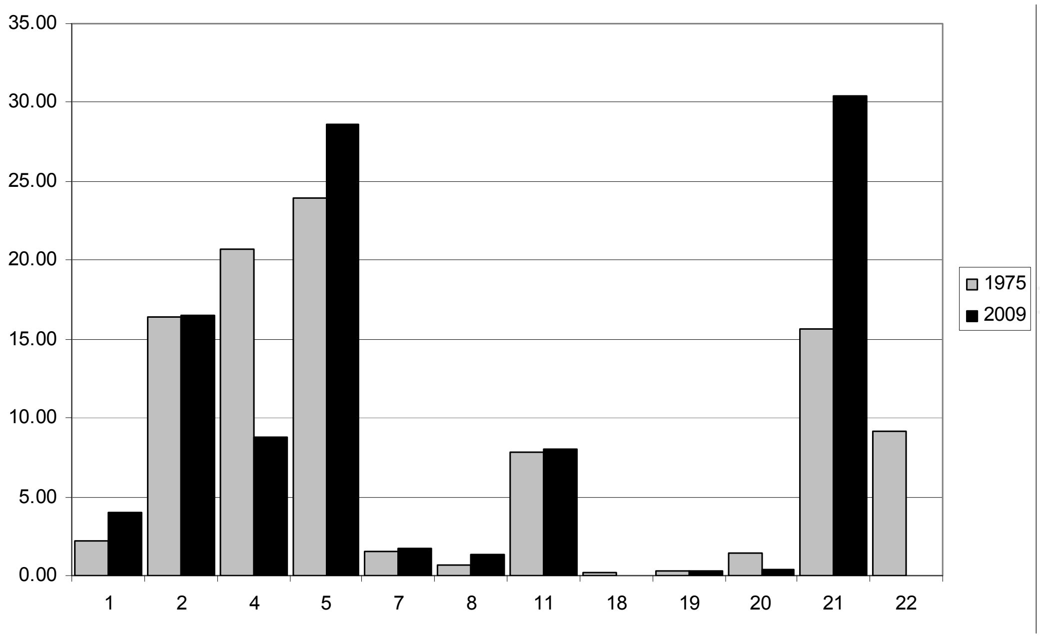

Figure 15. Relative frequency profile of land uses of each year in Torrelodones. The codes and the land uses are the same for Table 8.

Code	Land use	Number of patches	
		1975	**2009**
20	Agricultural and livestock settlements	15	5
1	*Quercus ilex* subsp. *ballota* Dehesa (high density of scattered trees)	8	4
2	*Quercus ilex* subsp. *ballota* Dehesa (intermediate density of scattered trees)	16	17
19	Reservoir	1	1
22	Areas under urban development	6	0
18	Dump	1	0
4	*Juniperus oxycedrus* , *Quercus ilex* subsp. *ballota* and *Cistus laurifolius* (high density woodland)	12	7
5	*Juniperus oxycedrus, Quercus ilex* subsp. *ballota* and *Cistus laurifolius* (intermadiate density woodland)	8	4
11	Pastures with scattered *Quercus ilex* subsp. *ballota* y *J. oxycedrus* subsp. *oxycedrus* trees	10	15
7	Riparian forest	6	6
8	Shrubby riparian vegetation	4	5
21	Urban area	9	12
	TOTAL	**148**	**104**

Table 9. Fragmentation value of each land use measured as number of patches in Torrelodones. This parameter has been calculated in 1975 and 2009.

5. Conclusions

This paper shows the multiscalar and multidisciplinary methods applied in landscape analysis using ecological, geographical and cartographical techniques. At PNA scale the comparative analysis of the vegetation and land use maps enabled us to identify five main change dynamics in the territory: urban development, scrub encroachment, forest encroachment, agricultural abandonment and new crops. Most of these dynamics were consequence of the abandonment of traditional activities or the increase in urbanised areas.

For a detailed scale three study cases were chosen. In Cerceda open woodland and shrub encroachment were more significant dynamics. Fragmentation measured was significantly higher in 2009 than in 1975 and conserved the same permeability. This is an area with few transformations by anthropic uses and that maintains the same vegetation types in both dates. The increase of road infrastructures, urban pressure and agricultural abandonment generated a homogeneous landscape in Fuencarral. This type maintains (2009) a great diversity of land uses, wastelands and habitats well preserved that have and interesting role such as ecological and territorial connectors. The most important changes in Torrelodones were located in urban areas consolidated between 1975 and 2009. At northwest edge N-VI highway introduced fragmentation and negatives effects with loss of permeability and connectivity.

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Acknowledgement

This research was partially funded by the Spanish Ministerio de Educación y Ciencia (projects CSO2009-12225-C05-02 and CSO2009-14116-C03-0102956-BOS).

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