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The fourth dimension in landscape analysis: changing of heritage and ecological values in the Évora cultural landscapes.

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Abstract

Time is one of the most important driving forces in Landscape Ecology. Time along with geosystem, biosystem and socialsystem determines landscape heterogeneity which reveals itself in different patterns and functions. Cultural Landscapes are the result of the interactions between man and environment along time.
Évora (the pre-roman *Ebora*), the most important town in Alentejo province (Southern Portugal) is involved by a cultural landscape where not only archeological sites and old built structures (walls, roads, bridges houses, etc.) of several epochs are present, but also old parcel networks and specific agro forestry pastoral systems, the *montados*, exist. Many of the limits of those parcels are materialized by vegetation galleries playing an important role in what concerns the landscape ecological quality of the area.
The work developed is a comparative study of the quality of the Évora cultural landscape between 1958 and 2007. This study is based on the interpretation of vertical aerial photos from 1958 and 2007, and on the use of GIS as a tool for the spatial and temporal analysis. The main goals are:

- To understand the contribution of time and human history in landscape structure;
- To study the changes from 1958 to 2007 in ancient cadastral systems and landscape ecological structure: focused in *montados* and ecological corridors
- To measure the contribution of ancient cadastral systems to the actual ecological structure

Key words: Heritage landscapes; ecological corridors; time, landscape ecology.

Introduction

Time is one of the most important driving forces in Landscape Ecology. Time along with geosystem, biosystem and socialsystem determines landscape heterogeneity which reveals itself in different patterns and functions. The relations between History and Ecology have been studied more deeply in the recent decades, having focused mainly in to kinds of topics: understand nature with the help of history or understand human history with the help of natural phenomena (Szabó 2010). To this author the main reasons to "Why history matters in ecology" are (1) because it aids to understanding current patterns and processes in nature; (2) because it foster better informed management and polity decisions and (3) because it places ecology and conservation in a wider, interdisciplinary context.

Time (History) in landscape ecology: cultural landscapes

Cultural Landscapes can be considered as 'illustrative of the evolution of human society and settlement over time, under the influence of the physical constraints and/or opportunities presented by their natural environment and of successive social, economic and cultural forces, both external and internal' (WHC, 2005, paragraph 47). This concept is then dynamic since cultural landscape is the product of a long-term, scientifically demonstrable nature/human interactive process (Fowler,

2006). Exploring how heritage demands newly focus on landscape, David Lowenthal (1993, 4) argues that 'the word landscape subsumes three vital concepts: nature as fundamental heritage in its own right; environment as the setting of human action and sense of place as awareness of local difference and appreciation of ancestral roots'. On the other hand 'linkages of present with past are felt to need not just isolated heritage icons but the cultural landscape's embedding framework' (Lowenthal, 1993, 5). The present character of many of these landscapes is a 'palimpsest of elements from the past and present' (Aplin, 2007, 430), where the persistence of plans law was more or less determinative, though the dynamics of the landscape morphology evolution can be considered, for certain authors, as a linear and ontogenetic model corresponding to the birth-life-dead scheme (Marchand, 2007, 3). Being the heritage value one of the types of values that can be conferred to the cultural landscapes, the most valuated concerning this aspect can be designated as '*heritage landscapes*' (Capelo et al., 2010).
Évora (the Lusitanian Ebora), the most important town in Alentejo province (Southern Portugal) is involved by a landscape with high heritage value where not only archeological sites and old built structures (walls, roads, bridges houses, etc.) of several epochs are present, but also old parcel networks and specific agro forestry pastoral systems, the *montado*s, exist.

Each one of these heritage landscape sub-types which are described below, play a very important role in the landscape, acting as corridors with functions of transport for people, materials, limits of properties, parcel boundaries, and others. Many of these are actually ecological corridors, by the fact of been connected to important vegetation galleries which function as habitat for many species as birds, mammals, reptiles, amphibians and insects.

• **The *montado*** is a typical south western Iberian Peninsula landscape, traditionally related with agro-silvo-pastoral systems where open formations of pure or mixture cork and / or holms oaks (and even other kinds of trees) composed the treelike layer under what a rotation of crops / fallows / pastures takes place. Traditionally, pigs, sheep and eventually other livestock, as bovines and sometimes goats, feed on acorns, shrubs and grasses under the trees, controlling the nutrient cycles (Pinto-Correia and Vos, 2004).These formations are actually under legal protection (Decree-Law 140/99, April 24 – Annex B-1 (republished by Decree-Law 49/2005, February 24); Directive 92/43/CEE, May 21 – Annex I; Decree-Law 169/2001, May 25, with alterations; Decree-Law 155/04, June 30) and can be considered as heritage landscapes.

• **The Roman Augustan field network system** (cadastral system), would result from a land division operation granted to native people when Roman Évora (*Ebora Liberalitas Iulia*) became a *municipium* (Clavel-Lévêque et al., 1995). Traces of a probable cadastral structure were identified with a 30-31º NO/SE orientation (the same than the *kardo maximus* and the *decumanus maximus* of the urban structure) and a theoretical matrix of 20 x 20 *actus* (710 x 710 m, approximately) (Clavel-Lévêque et al. 1995; Plana-Mallart 2002; Barata and Mascarenhas 2002).

• **The Late Roman Empire cadastral system** followed land *renormatio* operations in *Ebora* surroundings that have begun during the Dioclecian government and his colleagues with tax purposes (*jugatio*), as recognized in Lusitania at Pax Julia and Conimbriga (Mantas, 1990, 1996, Batista et al. 2010). This cadastral network, with the *centuria quadrata* module (710 x 710 m), shows an orientation close to N / S and is related with important existing roads (*kardo* and *decumanus* ways), cross roads and other structures. Certain alignments are coincident with administrative limits (Batista et al. 2010).

• **The Medieval cadastral network**
After the Reconquest, from the XIII century on, the pattern of the agricultural fields, on Évora surroundings, are arranged in rings around the city. Four rings of agricultural systems could be distinguished (Barata and Vilar, 1995, cit. by Barata and Mascarenhas, 2002, 126-128): in the first one, the nearest to the city, dominated the "ferragiais" (irrigated green fodder fields), or in alternative, the kitchen-garden parcels under a rotation regime. In the second ring the vineyards prevailed and occupied the best soils near the streams margins. In the third ring were the farms enclosing various crop fields (extensive cereal culture) with grazing land. Finally, outside this last

ring was grazing land. Several limits of the medieval parcels network are coincident with those of the roman period specially in areas near the city, in the East and Northwest quadrants (Mascarenhas and Barata, 1997). Nevertheless the medieval cadastral network could present parcels with irregular forms and various shapes (square, rectangular, long) depending more on the morphology of the terrain and the conditions of water access (Barata and Mascarenhas, 2002, 126).

Many of the marks of the referred three cadastral networks limits could be identified through the analysis of maps, aerial photographs and satellite images and are still materialized by various elements (road marks, slopes, old stone plain walls, property limits, canalized water lines and others).
According to the World Heritage Convention classification, if the *montado* landscape is clearly a type of *continuing* landscape, the three first ones can be placed between the *relict* (or *fossil*) and the *continuing* landscapes (Batista et al., 2010).

Ecological Corridors as Landscape Ecological Values

Ecological corridors are considered as one of the most important features in landscape, because of their important role in connecting patches, reducing fragmentation and isolation, transporting water, energy and materials.

Forman and Godron (1986) define corridors as 'narrow strips of land wich differ from the matrix on either side'. Hoechstetter (2009), argue that corridors can be regarded as a special case of a patch: a "longish" patch, which is separately considered because of its important functional role in landscapes. Corridors can also be defined according to their functional character – as "narrow strips of habitat surrounded by habitat of other types" (Farina 2006). Corridors are especially characterized by the connectivity over large distances and sharp environmental gradients from one side to the other (Forman and Godron 1986). According to these authors, three basic types of corridors can be distinguished:

- Line corridors – such as roads, hedgerows, propriety boundaries, drainage ditches and irrigations channels, rather narrow in their spatial extent and dominated throughout by edge species.
- Strip corridors - are wider bands with a centre interior environment that exhibit an abundance of interior organisms.
- Stream corridors – border water courses and vary in width according to the size of the stream, functioning as a transport medium for water and nutrients. They control water and mineral nutrient runoff, thus reducing flooding, siltation, and soil fertility loss.

Hoechstetter (2009) refers also:

- Anthropogenic corridors, referring for example to transportation routes like roads and railways, inflicting the problem of fragmentation upon the landscape.

Corridors have several ecological functions such as routes for animal movements, as habitat for species, as sources of environmental and biological effects on their surroundings. These types of features characterize all landscapes, but stand especially in landscapes with major human influence (Forman and Godron 1986).

In the present work we have considered as ecological corridors the linear elements that connect or divide patches in the landscape, with vegetation associated. We considered two types of ecological corridors:

Stream corridors – riparian corridors along streams and rivers
Line corridors – hedges along walls, fences and roads

We also distinguish in these types of corridors if they were arboreal, shrubby or stratified corridors, in order to identify changes in vegetation structure.

In Mediterranean conditions riparian corridors are very important habitats for many bird species and small mammals, reptiles and amphibian. In the study area the summer it's dry and hot, giving these ecosystems a great role for species preservation.

Hedge and road corridors are linked with human activity and history along time. The old marks leaved by ancient civilizations are responsible for many of the wall, roads and channels corridors as we describe earlier.

Material and Methods

The study area is located in Alentejo, South of Portugal, and it is composed by an area of 19x19 sqkm around the Évora City (figure 1).
In the present work we studied the relations between history and ecology by analyzing the relation between the old cadastral network and their contribution for the actual ecological corridors network. This study integrates the evolution of these marks and the ecological structure (corridors and *montados*) in the last 50 years (from 1958 to 2007-2008).

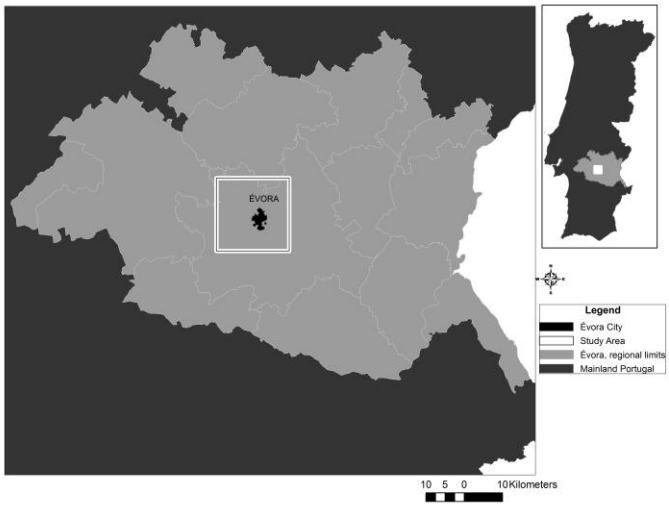

Figure 1 – Localization of the study area

The methodology developed uses GIS model detailed in figure 2. The cadastral network for the three epochs, (1) Roman Augustan cadastral network (NW/SE orientation), (2) Late Roman Empire cadastral network (N / S) and (3) Medieval cadastral network, were digitalized based on photo interpretation of aero photographs of 1958 and 2007 (figure 3) and on previews works done by Mascarenhas (1995).

The *montados* as well as the vegetation galleries were digitalized for the referred two dates (1958 and 2007). The information of 2007 *montados* spatial distribution and structure was collected from the "Land occupation and use of Évora District and Sousel Map" elaborated by the Intermunicipal Community of Central Alentejo in 2011 (Batista, 2011). The total area was compared to the photointerpretation made for 1958.

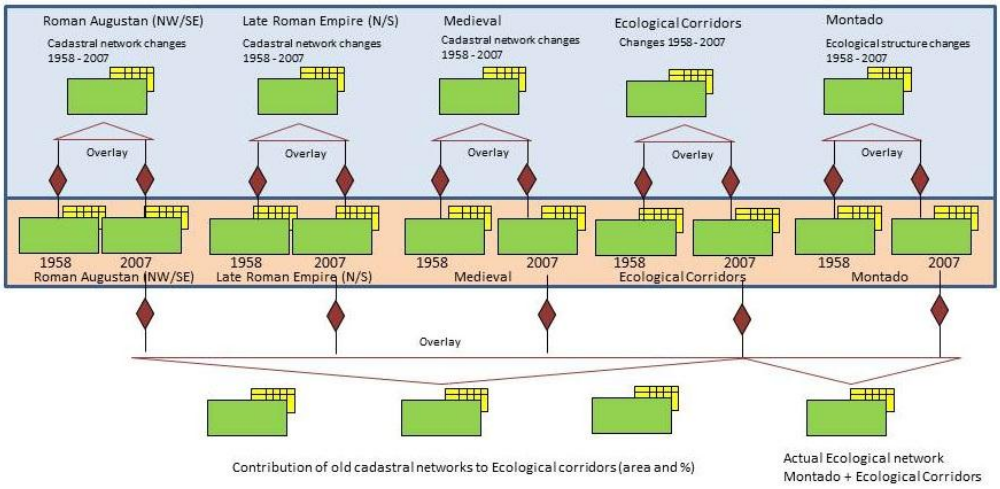

Figure 2 – GIS model for the time analysis and contribution of history to ecology in the study area

Results

Changes on cadastral network between 1958 and 2007

The old cadastral network has suffered, between 1958 and 2007, several human and natural impacts, which determinate the elimination of 25% of these ancient marks (table 1). The most important human activities which contribute to this event where:

- Agriculture intensification, with the use of heavy machinery and the enlargement of crop fields;
- The urban and suburban expansion of the Évora city, which had more impact in the medieval cadastral network (19%).

Table 1 – Old Cadastral Networks in 1958 and 2007 and changes

Old Cadastral Networks	*1958 (km)*	*2007 (km)*	*Changes (km)*	*Changes (%)*
Roman Augustan cadastral network (NW/SE)	382,66	240,33	-142,33	-37
Late Roman Empire cadastral network (N/S)	390,42	340,37	-50,05	-13
Medieval cadastral network	40,37	32,75	-7,62	-19
Total	813,45	613,45	-200	-25

The figure 3 presents the (1) Roman Augustan cadastral network (NW/SE orientation), for 1958 and 2007 and the erosion from 1958 to 2007 (in black), (2) Late Roman Empire cadastral network (N / S), for 1958 and 2007 and the erosion from 1958 to 2007 (in black), and (3) Medieval cadastral network, for 1958 and 2007 and the erosion from 1958 to 2007 (in black).

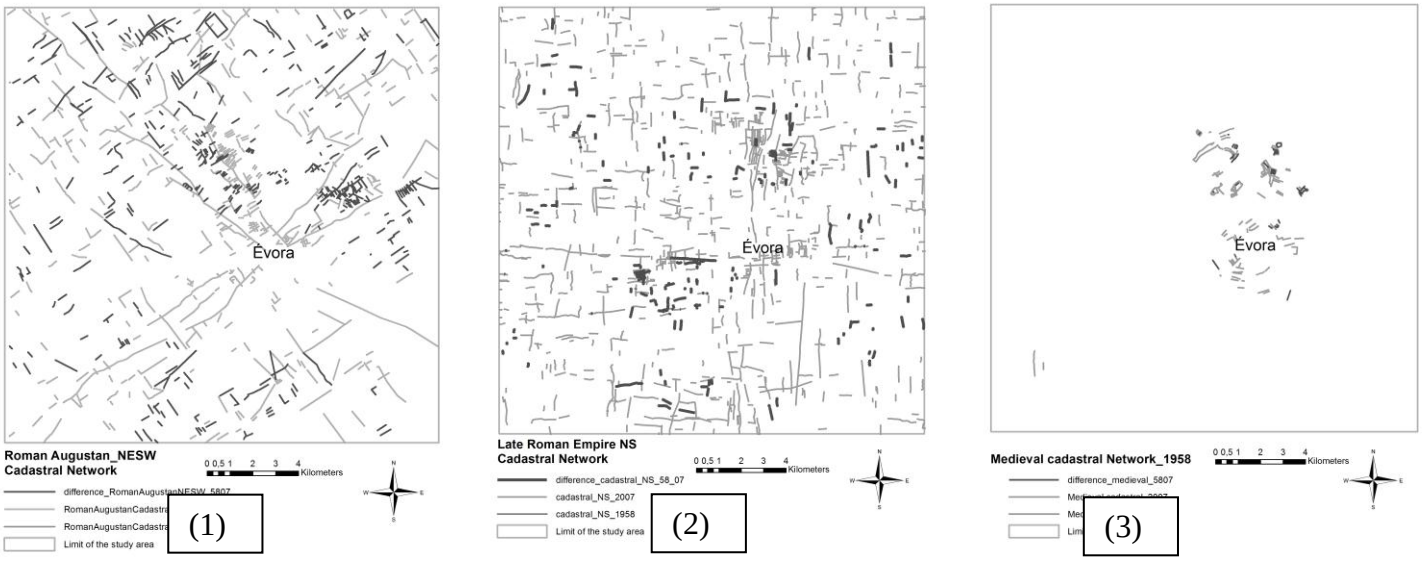

Figure 3 –(1) Roman Augustan cadastral network (NW/SE orientation; **(2)** Late Roman Empire cadastral network (N / S); (3) Medieval cadastral network, for 1958 and 2007 and changes

Changes on ecological corridors between 1958 and 2007

From 1958 to 2007 the total length of ecological corridors have improved 15,6 km (from 346,6 to 362,2 km - +4,5%). Despite this slightly increment in length we assisted at the improvement of riparian vegetation in their contiguity, structure and width, as we can observe in figure 4. This is observed in stratified corridors, which had an improvement of 1516%, (from 2,5 km to 40,4 km). This is more interesting when we analyze the changes in corridors structure (table 2). We assisted at the increase of stream and road corridors and to a decrease of wall corridors.

Table 2 – Corridors structure in 1958 and 2007

	1958 (km)	*2007 (km)*	*Changes (km)*	*Changes (%)*
Stream corridors	188,1	200,7	+12,6	+6,7
Road corridors	55,1	61,3	+6,2	+11,3
Wall corridors	103,4	100,2	-3,2	-3,1
Arboreal corridors	227,8	218,3	-9,5	-4,2
Scrubs corridors	116,3	103,5	-12,8	-11,0
Stratified corridors	2,5	40,4	+37,9	+1516,0
Total ecological corridors	346,6	362,2	+15,6	+4,5

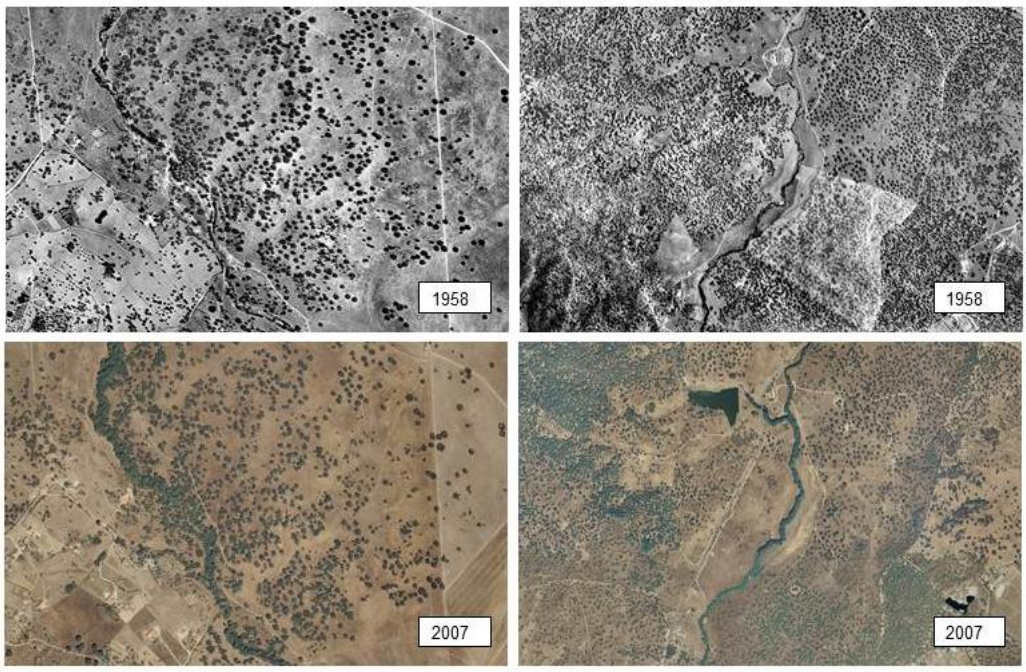

Figure 4 - Examples of stream corridors in 1958 and 2007

This can be explained by the fact that in the fifty's there were much more labor work in the countryside, and the streams were much more used for cattle and sheep's water supply, and for this the streams were cleared from vegetation. There is also the fact that in the 80s, the Portuguese legislation begins to protect the stream boundaries by defining the National Ecological Reserve (REN), and in the beginning of the 21th century farmers must have permission to clean the streams. At the same time there were build many small and median lakes and dams which substitute the necessity of stream water for animal breeding. The corridors network is observed in figure 5 where we can distinguish them by theirs type and structure and also the increase from 1958 and 2007.

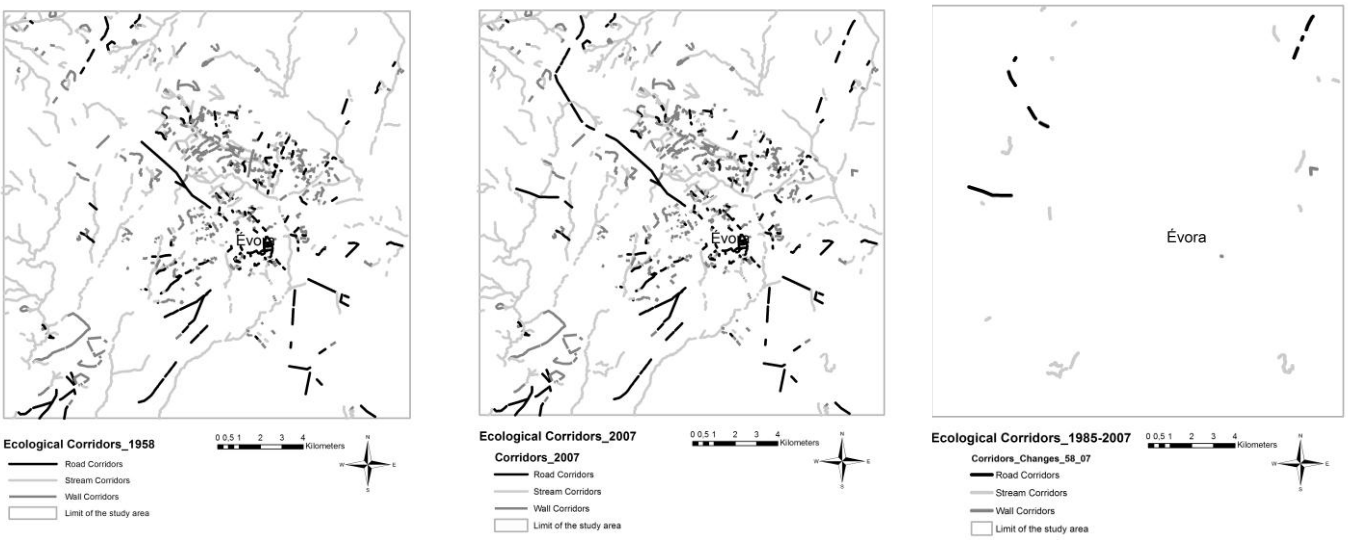

Figure 5 - Ecological corridors (stream, road and wall) in 1958, 2007 and changes between 1958 and 2007.

Changes on montado

The total area of *montado* was reduced in 78,24 hectares. In the total area (36.100,00 ha) this is quite irrelevant (-0,59%). However we assisted to several different situations more perceptible in table 2:

- Expand of the area by natural reforestation;
- Expand of the area by new plantation;
- Increase of *montado* density, with the natural growing of trees during fifty years;
- Decrease of *montado* density and area, with the cut of trees for intensive agriculture, dams, roads and urban expansion;

In the figure 6 is represented the geographic localization of the *montado* in the study area, in 1958 and 2007, referring to the gains (+1212 ha) and losses (-1290 ha) of area, between 1958 and 2007.

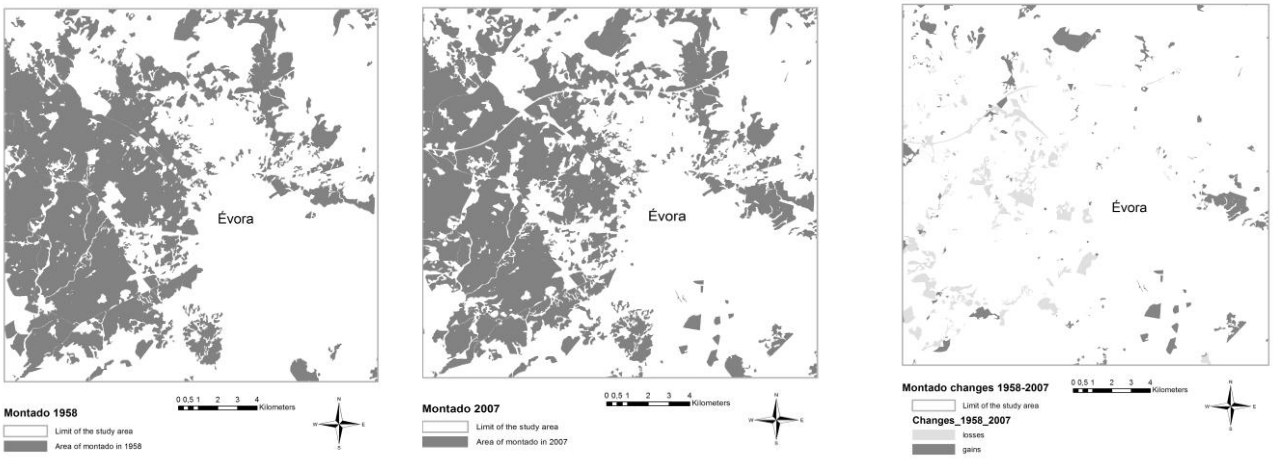

Figure 6 - *Montado* in 1958 and 2007 and gains and losses from 1958 to 2007

Table 3 – *Montado* in 1958 and 2007

	1958 (ha)	*%*	*2007 (ha)*	*%*	*Changes (ha)*	*Changes (%)*
Dense *Montado*	9280,48	70,2	9454,48	72,0	+174,00	1,87
30-50% of trees density	2846,11		2758,26			
>50% of trees density	6434,37		6696,22			
Open *Montado* (10-30% of tree density)	2177,37	16,5	3268,61	24,9	+1091,24	+50,12
Sparse trees (<10% of tree density)	1694,36	12,8	158,55	1,2	-1535,81	-90,64
Others	61,23	0,5	253,56	1,9	+192,33	+314,11
Montado total	13213,44		13135,20		-78,24	-0,59

The contribution of old cadastral networks to ecological corridors

GIS was the fundamental tool to overlay the geographic information concerning all the themes we studied. This permitted to identify what were the ancient remarks that contribute the most for the ecological corridors network. We observed that 41% (147,21 of the 362,2 sqkm) of the total ecological corridor network is provided by the old cadastral networks (table 4) The Roman Augustan cadastral network NE-SW provides 20%, the Late Roman Empire 17% and Medieval 4%. These contributions are essentially linked to roads and wall corridors (figure 8).

Table 4 – Contribution of old cadastral networks to ecological corridors (2007)

Old Cadastral Networks	*2007 (km)*	*%*
Roman Augustan cadastral network (NW/SE)	70,75	20
Late Roman Empire cadastral network (N/S)	61,13	17
Medieval cadastral network	15,33	4
Total	147,21	41
Total Ecological Corridors	362,20	

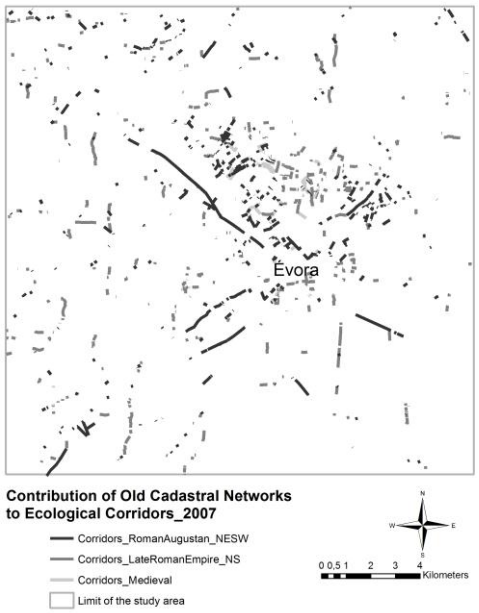

Figure 7 – Contribution of Old Cadastral Networks to the ecological corridors network

Discussion

Time is really important to the comprehensive analysis of landscape ecology. The interdisciplinary approach of landscape ecology with the connection with history can bring us a new understand of the territory, perceiving the importance of man in the negative and positive changes of the landscape. In fact in the study area we have the contribution in 41% from the old cadastral

networks to the actual ecological corridors network. We have also the *montado,* one of the most important cultural landscapes in Alentejo, in which the presence of man is a main condition to the maintenance of cultural landscape value as a societal good.
In our time analysis we observed that although we have assisted to the destruction of many ancient marks related with limits of ancient cadastral networks (-200 km), we have also assisted to the improving of the landscape ecological structure (+15,6 km) and to the "stabilization" of the *montado* area.
The present study is also a contribution to future research applied to OTALEX C area, in which there are several important ancient Roman towns like Merida, in Extremadura, Spain and to conservation purposes, as happened in Italy (Caravello & Giacomin, 1993; Caravello & Michieletto, 1999).

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Bibliography

Aplin, G., 2007: *World Heritage Cultural Landscapes*, *International Journal of Heritage Studies*, 13 (6): 427-446.
Batista, T.; Mascarenhas, J.M. de; Mendes, P. & Mantas, V., 2010: *Heritage Landscapes in Évora surroundings: a GIS approach*, in: Yildizci, A.C. et al. (eds.), *Proceedings of the 27 th. ECLAS Conference "Cultural Landscape"* (Istambul, 29 Sept.-02 Oct.), Istambul, pp.791-802.
Batista T., 2011: *Carta de ocupação/uso do solo do Distrito de Évora e Concelho de Sousel – Legenda Corine Land Cover Nível 5*. (*Land cover/Land use cartography for Distrito of Évora and municipality of Sousel – Corine Land Cover legend level 5).* CIMAC Edts, Évora. Portugal.
Barata, F. and Mascarenhas, J.M. de, 2002: *Preservando a Memória do Território - O Parque Cultural de Tourega - Valverde (Preserving the Land's Memories / The Tourega-Valverde Cultural Park).* Évora: CEEM - Universidade de Évora.
Batista, T., 2000: *Using GIS to analyze biodiversity on agro-ecosystems, in the Évora Region*. Master Thesis. Évora: University of Évora.
Bennett, EM., 2003: *Soil phosphorus concentrations in Dane County, Wisconsin, USA: an evaluation of the urban-rural gradient paradigm*. Environ. Manag., 32 4 (2003), pp. 476–487
Capelo S., Barata F.T. & Mascarenhas, J. M. de, 2010 : *Why cultural landscapes have different values? Thinking about heritage landscape evaluation and monitoring tools*. *Journal of Landscape Ecology* , 4(1): 5-17.
Caravello, G.U. and Giacomin, F., 1993: *Landscape ecology aspects in a territory centuriated in Roman times*", *Landscape and Urban Planning*, 24: 77-85.
Caravello, G. & Michieletto, 1999: *Cultural Landscape: Trace Yesterday, Presence Today, Perspective Tomorrow For "Roman Centuriation" in Rural Venetian Territory*, *Research in Human Ecology*, 6(2): 45-50.
Clavel-Lévêque, M., Plana-Mallart, R. and Vignot, A., 1995: *Évora - Partie I: La ville romaine d'Ebora et son territoire; Partie II : Organisation et aménagement de l'espace rural; Partie III : Approche morphologique et cartographique des images satellitaires*. In : J.M. de Mascarenhas , coord., 1995, Vol.3 (Anexo I), 1-90. Unpublished internal report.
Farina, A., 2006: *Principles and Methods in Landscape Ecology: Towards a Science of the Landscape* , Springer, Dordrecht, 412 p.
Forman, R.T.T. & M. Godron, 1986: *Landscape Ecology*. John Wiley and Sons, Inc., New York, NY, USA.
Fowler, P., 2006: *World Heritage Cultural Landscapes: What are they?*, *World Heritage Review*, 44. http://whc.unesco.org/uploads/activities/documents/activity-477-2.doc
Hoechstetter S., 2009: *Enhanced methods for analyzing landscape structure. Landscape metrics for characterizing three-dimensional patterns and ecological gradients*. " Reihe, Fernerkundung Angew. Geoinformatik

Lowenthal, D., 1993: *Landscape as Heritage: National Scenes and Global Changes*. In J.M. Fladmark, editor. *Heritage : Conservation, Interpretation and Enterprise*. London: Donhead : 3-15.
Marchand, C., 2007 : *Que faire de l'héritage ?*, In : *Les Actes du Premier Colloque d' Archéogéographie* (Paris, Sept. 2007).
http://www.archeogeographie.org/index.php?rub=bibli/colloques/pre-actes/marchand
Mascarenhas, J. M., 1995 : «ÉVORA: Archéologie et Conservation du Paysage et Environnant » In: M. Clavel-Lêveque and R. Plana-Mallart R., eds., *Cité et Territoire.* Ier. Colloque Européen (Béziers, 1994). *Annales Littéraires de l'Université de Besançon*, 565 : 227-230.
Mascarenhas, J.M. de, coord., 1995: *Análise da Região Envolvente de Évora numa perspectiva de Ecologia da Paisagem.* Relatório do Projecto STRIDE.(Analysis of the surroundings of Évora in a landscape ecology perspective. Project Report STRIDE). University of Évora: Center of Studies of Mediterranean Ecossystems, 2 vols. + 3 vols. (Annexes) + Maps. Unpublished internal report.
Mantas, V., 1990: *Teledetecção e urbanismo romano*. (*Remote sensing of romman urbanism). Geociências. Revista da Universidade de Aveiro* , 5 (1): 75-88.
Mantas, V., 1996: "O espaço urbano nas cidades do Norte da Lusitânia" (The urban space in the cityes of North Lusitania), In: A. R. Colmenero, ed. *Los Origenes de la Ciudad en el Noroeste Hispánico*. Vol. I., Lugo: 355-391.
Mascarenhas, J.M. de and Barata, F. Th., 1997: *O Território de Ebora, e a Organização e Ordenamento da Paisagem Envolvente*. *(The Ebora Territory and the organization and management of the surrounding landscape)* In: P. Sarantopoulos, coord., *Paisagens Arqueológicas a Oeste de Évora (Arqueological Landscapes of West Evora)*, Évora: Câmara Municipal de Évora, 1997, 61-71.
Pinto-Correia and Vos, 2004: *Multifunctionality in Mediterranean landscapes – past and future*, In: Jongman, R. ed., *The New Dimensions of European Landscapes*. Berlin: Springer Verlag : 135-164.
Plana-Mallart, R., 1995: *Ebora et son territoire* ,In: M. Clavel-Lévêque and R. Plana-Mallart, eds. *Cité et territoire*. Ier. Colloque Européen (Béziers, 1994). *Annales Littéraires de l'Université de Besançon*, 565 : 231-242.
Plana-Mallart, R. and Mascarenhas, J.M. de (coll.), 2002: *Le territoire d'Ebora en Lusitanie* , In : M. Clavel – Lévêque and A. Orejas, dir., *Atlas historique des cadastres d'Europe II*. EUR 19717. Brussels: Commission Européenne, Direction Générale de la Recherche, Dossier 7, 2002, 10 p..
Szabó P., 2010: *Driving forces of stability and change in woodland structure: a case-study from the Czechlowlands.* For Ecol Manag 259:650–656
WHC, 2005: *Operational Guidelines for the Implementation of the World Heritage Convention*. UNESCO World Heritage Centre.