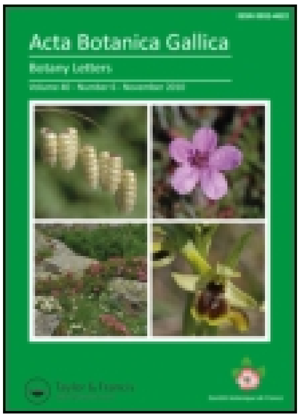

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Contribution to Local Landscape Units definition in OTALEX II

Teresa Batista [a b] , Paula Mendes [a] , Carlos Vila-Viçosa [a] , Mafalda Veigas [a] , Joana Cavaco [a] , José Cabezas [c] , Luis Pozo [c] , Natalia Arancibia [c] , Rodrigo Paiva-Ferreira [a] & Carlos Pinto-Gomes [a]

[a] Departamento de Paisagem, Ambiente e Ordenamento /Instituto de Ciências Agrárias e Ambientais Mediterrânicas (ICAAM), Universidade de Évora (Portugal), Rua Romão Ramalho, n° 59, P-7000-671, Évora, Portugal

[b] Intermunicipal Community of Central Alentejo (CIMAC), Rua 24 de Julho, n° 1, 7000-673, Évora, Portugal

[c] Universidad de Extremadura, Departamento de Física, Área de Ecología, Edificio de Rectorado Avda. de Elvas, s/n, 06071, Badajoz, Portugal

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Contribution to Local Landscape Units definition in OTALEX II

Contribution à la définition des unités locales du paysage en OTALEX II

Teresa Batista[a,b]*, Paula Mendes[a], Carlos Vila-Viçosa[a], Mafalda Veigas[a], Joana Cavaco[a], José Cabezas[c], Luis Pozo[c], Natalia Arancibia[c], Rodrigo Paiva-Ferreira[a] and Carlos Pinto-Gomes[a]

[a]*Departamento de Paisagem, Ambiente e Ordenamento /Instituto de Ciências Agrárias e Ambientais Mediterrânicas (ICAAM), Universidade de Évora (Portugal), Rua Romão Ramalho, n° 59, P-7000-671 Évora, Portugal;* [b]*Intermunicipal Community of Central Alentejo (CIMAC), Rua 24 de Julho, n° 1, 7000-673 Évora, Portugal;* [c]*Universidad de Extremadura, Departamento de Física, Área de Ecología, Edificio de Rectorado Avda. de Elvas, s/n, 06071 Badajoz, Portugal*

Abstract: OTALEX II is the Territorial and Environmental Observatory of Alentejo (Portugal) and Extremadura (Spain), co-financed by POCTEP, developed with the cross-border collaboration of several Portuguese and Spanish bodies. It is composed of a Spatial Data Infrastructure (SDI) created in 2007, SDI-OTALEX (www.ideotalex.eu), which is an exchange platform for geographic information and Webmapping services among project partners. The integration of environmental indicators such as landscape indicators, for the characterization and monitoring of the Alentejo Extremadura area is one of the most relevant components of the project. This paper reports the achievements in defining Local Landscape Units (LLU) for a pilot area of Central Alentejo – the Pardiela river basin. The methodological approach applied Geographic Information System tools to integrate soils, geomorphology and land cover. The land cover map applies the CORINE Land Cover Legend Level 5 to Central Alentejo at a scale of 1 : 10,000. This map contains variables related to vegetation, hydrology (streams and water bodies) and human settlements (buildings, equipment, roads). The validation of the results obtained for LLU with previously defined Landscape Units and potential vegetation mapping confirm the reliability and replicability of the present methodology for similar territories.

Keywords: Landscape indicators; Local Landscape Units; OTALEX

Resumé: OTALEX II c'est l'Observatoire Territoriale pour l'Environnement au Alentejo (Portugal) et l'Estrémadure (Espagne), co-financé par POCTEP avec la collaboration entre plusieurs entités Portugaises et Espagnols de l'trans-frontière de les deux pays. Il est composé d'une infrastructure d'information spatiale (SDI), créée en 2007, SDI-OTALEX (www.ideotalex.eu) qui est une plate-forme d'échange d'information géographique et des services Webmapping pendant les partenaires du projet. L'intégration d'indicateurs environnementaux intègre les indicateurs de paysage comme un des components le plus pertinent du projet, pour la caractérisation et le suivi de la région Alentejo et Estrémadure. Cet article présent les résultats obtenus dans la définition des unités locales du paysage (dégroupage) pour une zone pilote de l'Alentejo Central - la bassin de la rivière Pardiela. L'approche méthodologique applique des instruments de géomatique (SIG) pour intégrer les sols, la géomorphologie et la couverture terrestre. La carte d'occupation du sol applique la légende niveau 5 du CORINE Land Cover, développé par Guiomar et al (2009) et appliqué au Centre de l'Alentejo, a l'échelle 1:10.000. Cette carte a des variables liées à la végétation, l'hydrologie (cours d'eau et plans d'eau) et les établissements humains (bâtiments, équipements, routes). La corroboration des résultats obtenus a été réalisée avec les unités de paysage défini par Cancela d'Abreu et al (2001), et une carte de végétation potentielle, mis au point, confirme la fiabilité et la reproductibilité de la présente méthodologie.

Mots-clés: Indicateurs du paysage; OTALEX; Unités Locales du Paysage

Introduction

The definition of landscape has been continually expanded by authors from a variety of scientific areas (Naveh and Lieberman 1984; Forman and Godron 1986; Zonneveld 1990; Farina 1998).

The first reference to the term landscape appears in the Book of Psalms, 48.82 on the aesthetic value of a Jerusalem landscape (Naveh and Lieberman 1984); however, the etymology of the word landscape in Anglo-Saxon seems to have been associated with the German word *landschap* introduced by landscape painting (Zonneveld 1990). The first definition of landscape as a subject was by the scientific biogeographer Alexander Von Humboldt in the nineteenth century as "the character of a whole country" (Ingegnoli 2002).

*Corresponding author. Email: tbatista@cimac.pt

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In 1850, Rosenkranz defined landscape as "systems of all the kingdoms of nature locally and hierarchically organized" (Bastian 2001). In 1967, Neef characterized landscape as a part of Earth's surface with a uniform structure and a functional pattern (Kronert et al. 2001).

Forman and Godron (1986) give it a landscape ecology perspective, defining it as a heterogeneous area, comprising a cluster of interactive ecosystems that are repeated continuously in a similar manner.

The landscape definition in 1996 was considered by Farina (1998) as the most consensual, "A piece of land which we perceive comprehensively around us without looking closely at single components and which looks familiar to us".

To Zonneveld (1989), landscape should be analysed as a three-dimensional system, a combination of topological dimension with the vertical heterogeneity, chorological size, horizontal heterogeneity and overall relationship within the landscape, as a holistic unit. Landscape should not be seen merely as the sum of geofactors but as a true integration of them. Hence, landscape will exist in the inorganic sphere, biosphere and sociosphere (Bastian 2001).

Landscape should be considered as a complex whole that is more than the sum of its composing parts. This indicates that all elements in the spatial structure of the landscape are related to each other and form a unique complex system. Landscape appears as part of the earth surface complex system, with multiple interactions with multiple elements (e.g. bedrock, water, air, plants, animals, man) or units (Zonneveld 1979).

A land unit is a tract of land combination of edapho-climatic conditions and homogeneous vegetation units, at a set scale level (Zonneveld 1979, 1995; Velázquez 1992). Although it is a hypothetical construction, the land unit concept is used for many practical purposes, like reducing the survey costs of landscape attributes (resources), e.g. the land unit or physiographic survey (mapping) approach in soil, vegetation and landscape surveys; and as a basis for the evaluation of a landscape's suitability for any kind of land use (Zonneveld 1989).

In this study we propose and test a conceptual methodology to create Local Landscape Units (LLU), defined as the smallest landscape mapping unit, at a management and planning scale. LLU are important analysis tools to provide a better understanding and management of the landscape at a local level. This is applied to a pilot area in Central Alentejo: the Pardiela River Basin.

To create the LLU we analysed the elements with major influence on landscape from a holistic point of view. In this sense, the integration of hereditary factors such as geomorphology or soil properties is important as well as human activity for land cover and land use (Vos 2000). In this study we selected four elements that reveal

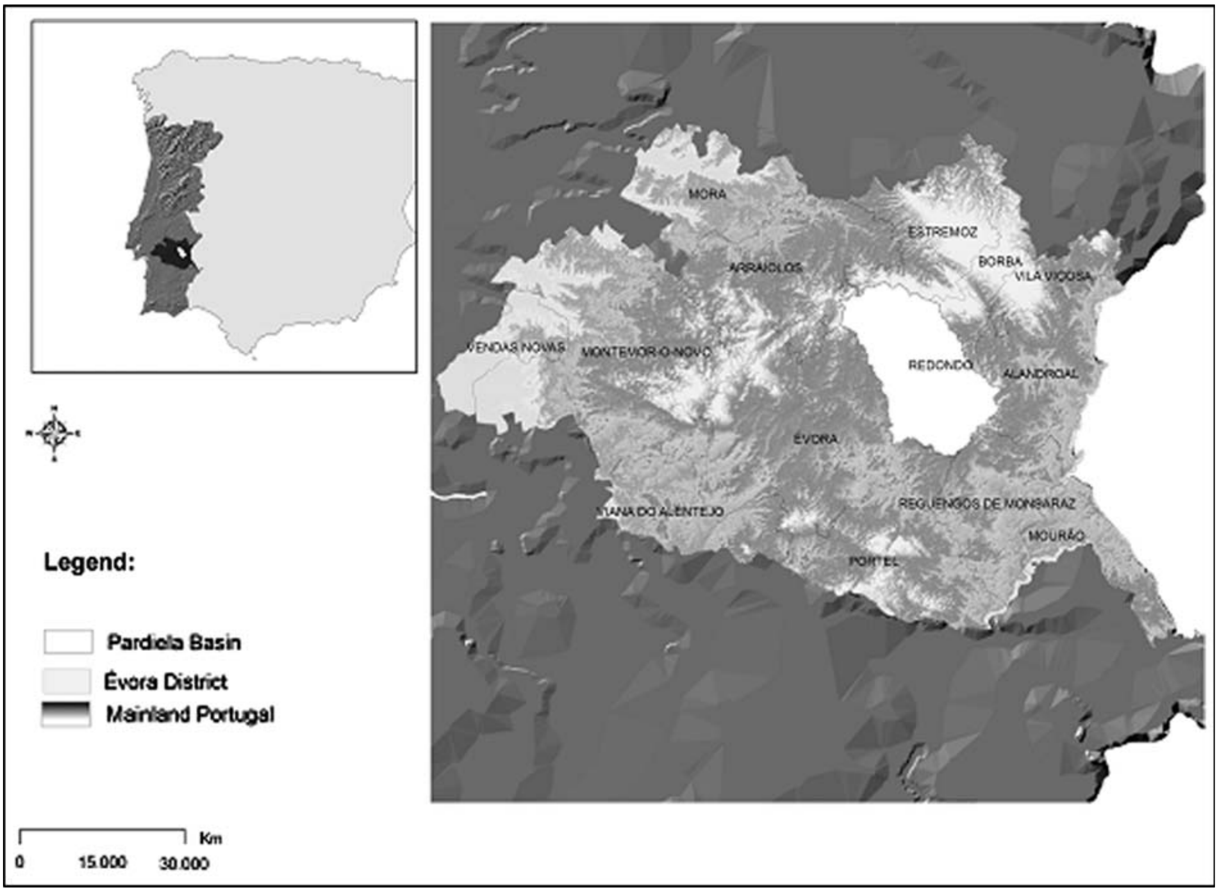

Figure 1. Study area.
Figure 1. Zone d'étude.

the study area's main characteristics: land cover, geology, relief and soils.

To validate the obtained results, the LLU were compared with the Landscape Units Map developed by Cancela d'Abreu, Pinto-Correia and Oliveira (2002) for the Portuguese mainland at a 1 : 500,000 scale, and with the Climatophilous Vegetation Series Map of the Pardiela River Basin.

Study area

The Pardiela River Basin is located in Central Alentejo, occupying an area of 518 km^2, and belongs to the Degebe River Basin within the Guadiana River major hydrographic system (Figure 1). It has mainly a rolling topography with a medium altitude of 254 m, although at the extreme northeast of the basin the gentle slopes change to the rougher relief of the Morena Mountains (with an maximum altitude of 655 m).

Geomorphologically, the Pardiela Basin relies on the Ancient Massif on the Ossa Morena geostructure. The basin is mainly constituted by igneous rocks (granites, granodiorites and tonalites) and metamorphic rocks, with emphasis on Ossa and Barrancos formations banded in a northwest–southeast direction. The first comprises mainly schists and greywackes and the second comprises schists, greywackes and conglomerates. At the eastern edge, the basin is constituted by the Moura Sedimentary–Vulcan complex (Moura Schists), which comprises mainly phyllites, psammitic and basic volcanites. At the northern limit, this area is crossed by the Grande filão do Alentejo, essentially consisting of tholeiitic rock and dolerite (Carvalhosa *et al*., 1987).

In biogeographical terms the Pardiela river basin is located in the Lusitan–Extremadurean Subprovince, namely in the Marianic–Monchiquensean Sector, in Alentejano District. This territory occupies mainly the mesomediterranean, upper dry to subhumid bioclimatic stages that can reach the upper thermomediterranean. The *Montados* in siliceous soils resulting from the degradation of the *Pyro-Quercetum rotundifoliae* holm oak woodlands and *Sanguisorbo-Quercetum suberis* cork oak woodlands that dominate the vegetal landscape. In its understorey are the *Ulici eriocladi-Cistetum ladaniferi* and *Erico australis-Cistetum populifolii* shrublands, among the common shrubby communities of *Retamo sphaerocarpae-Cytisetum bourgae*. The narrow-leafed ash woodlands (*Ficario-Fraxinetum angustifoliae*) and the *Salicetum atrocinereo-australis* willow woodlands occur frequently in this edapho-hygrophilous phytocoenotic district. This riparian woodland presents as subserial vegetation of *Holoschoeno-Juncetum acuti*, *Trifolio-Holoschoenetum* and *Juncetum rugosi-effusi* swards, among *Rhamno-Prunetea* thick scrublands. The hygrophilous or perennial grasslands of *Gaudinio fragilis-Agrostietum castellanae*, *Pulicario paludosae-Agrostietum pourretii* and *Loto subbiflori-Chaetopogenetum fasciculati* are also important in this area (Costa et al. 1998).

Material and methods

The LLU are based on a land cover map that applies the hierarchical CLC5 legend developed by Guiomar et al. (2006, 2009), with 295 land cover classes at a scale of 1 : 10,000 (Batista, 2011). The land cover map was made,

Table 1. CLC classification.
Tableaux 1. Classification de la CLC.

CLC	Description	Classification
334	Moist areas	1
511	Water streams	2
512	Water bodies	2
111	Continuous urban area	3
112	Discontinuous urban area	3
121	Industrial areas	3
122	Roads	3
124	Airport	3
131	Mines	3
132	Urban and Industrial waste areas	3
133	Construction areas	3
141	Green areas	3
142	Sport areas	3
212	Arable lands (irrigated)	4
213	Rice	4
222	Orchards	4
242	Complex parcel systems	4
241	Arable lands (not irrigated)	5
221	Vineyards	5
243	Olive groves	5
241	Annual and permanent cultures	5
231	Pasture	6
332	Burned areas	7
322	Scrubland	8
244	Agroforestry (Dense Montado)	9
244	Agroforestry (Open Montado)	10
313	Forest (mixed)	11
313	Forest (mixed riparian)	12
311	Broad-leaf forest	13
312	Coniferous forest	14
331	Bare soil	15
311	Broad-leaf forest (holm oak and cork oak) dense	16
311	Broad-leaf forest (holm oak and cork oak) open	17

Table 2. Soil classification.
Tableaux 2. Classification du sol

Soil class	Classification
Lithosols	1
Regosols	2
Alluvial soils	3
Humic entisols	4
Entisoils	5
Clay soils	6
Brown Mediterranean soils	7
Brown Mediterranean calcareous soils	8
Yellow and red Mediterranean soils	9
Brown calcareous soils	10
Yellow and red calcareous soils	11
Lowland soils	12

using digital ortophotomaps from Portuguese Forest Regional Direction, 2005, followed by field validation at the end of 2008. This map illustrates 17 classes, according to the main land use (Table 1).

Relief has been analysed and classified using a digital elevation model with 25 × 25 m pixel. This map has been reclassified using three altimetry classes according to area roughness (class 1, between 0 and 200 m; class 2, 200–400 m, and class 3, 400–655 m).

Geology used a map from the Geological and Mining Institute of Portugal, which has 71 geological classes at 1 : 50 000 scale. To create the LLU the geological map was reclassified into four classes, according to the most important geological substrate characteristics: Sand, Limestone, Volcanic rocks (like granites, granodiorites and tonalites), and Metamorphic rocks (like schists and greywakes).

The soils map has been developed by the Portuguese Institute of Hydraulic, Rural Engineering and Environment and has 71 combined classes at a scale of 1 : 25,000 that have been combined into 12 main soil classes, following Carvalho Cardoso (1965) (Table 2).

All information was combined and interpreted using the ARCGIS 9.3 Spatial Analyst Tool, specifically the Map Algebra Tools (Figure 2). At the end of the process the generalization function (aggregate tool) was used, which simplifies and analyses on different major scales. The Aggregate Function resamples an input raster to a coarser resolution based on a specified aggregation strategy (Max). Depending on the specified value for the cell factor (in this case, 4), the spatial extent of the input cells will not cover the same extent for the last cell, in a row or column, as the output raster. When this occurs, the value for the last output cell can be calculated with the available cells from the input raster that fall, within the extent (Expand). This function allows the aggregation of cell locations based on sum, mean, median, minimum or maximum values, within a spatial window, which is determined by a specified neighbourhood.

Cancela d'Abreu, Pinto-Correia and Oliveira (2002) landscape units have been created according to the concepts and methodology used in the study *Identification and characterization of landscape in continental Portugal*, which was undertaken by the Landscape and Biophysical Planning Department of Évora University for the General Direction for Spatial Planning and Urban Development (DGOT-DU) at the Ministry of the Environment and Spatial Planning, between 1999 and 2001. The result is a flexible approach that combines objective analysis with a more subjective assessment, which the team considered fundamental for a true understanding of landscape.

The landscape units from Cancela d'Abreu, Pinto-Correia and Oliveira (2002) divided this territory into four landscape units: The Montados and Grasslands from Central Alentejo, Alandroal and Terena land unit, Reguengos land unit and the Ossa Hills (Figure 3).

The Pardiela vegetation map (Figure 4) has been developed at the OTALEX II project with the characterization of potential climatophilous vegetation in the river basin its main goal. It combines field surveys and spatial modelling using the methodology developed by Paiva Ferreira and Pinto Gomes (2010) for the Potential Vegeta-

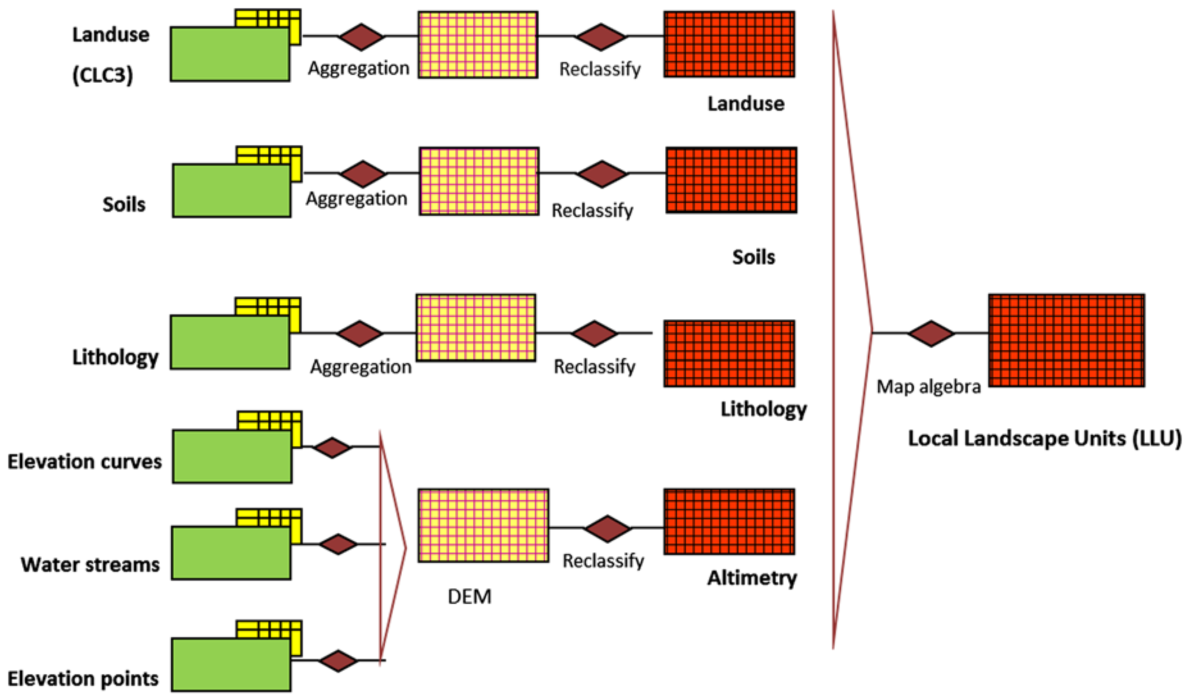

Figure 2. Spatial model.
Figure 2. Modèle spatial.

tion map and Monteiro-Henriques (2010) bioclimatic maps. This territory presents the climatophilous vegetation series: *Pyro bourgaeanae-Querco rotundifoliae* S. (Secundarious), *Sanguisorbo hybridae-Querco suberis* S., *Aro italici-Oleeto sylvestris* S. and *Lonicero implexae-Querco rotundifoliae* S. (Figure 4).

Results and discussion

This methodology led to the detailed division of the Pardiela Basin, with 278 LLU identified. This reflects the importance of scale in the definition of landscape pattern and confirms the complexity and heterogeneity of the territory. The LLU vary widely in type and size, reflecting the heterogeneity and diversity of the Pardiela River Basin, predominantly concerning organizational scale and pattern (Figure 5).

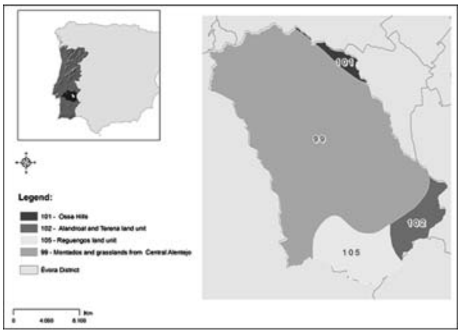

Figure 3. Pardiela Basin Landscape Units (Cancela d'Abreu, 2002).
Figure 3. Unités du Paysage de la Rivière du Pardiela (Cancela d'Abreu, 2002).

Comparing the LLU with the biggest landscape units from Cancela d'Abreu, Pinto-Correia and Oliveira (2002), there is coincidence mainly in the Central Alentejo Montados unit, Reguengos de Monsaraz land unit and Ossa Mountain range unit; however, on the Alandroal land unit the similarities are not easy to establish because this landscape unit is very heterogeneous.

The Central Alentejo *Montados* and Grass land units are coincident with the Montados landscape units, which are divided into 71 land units according to substrate, relief and tree density.

The Ossa Mountain range unit occupies a very small part of the Pardiela River Basin, at the extreme north. This area is mainly occupied by pine and eucalyptus forest with a great problem of recurrent fire cycles. The LLU split this territory into two small areas: a Pine Forest land unit and a Shrublands land unit.

The Reguengos de Monsaraz unit is split into 35 agriculture LLU. This area is mainly characterized by agriculture and pasture areas on calcareous soils under a rolling topography.

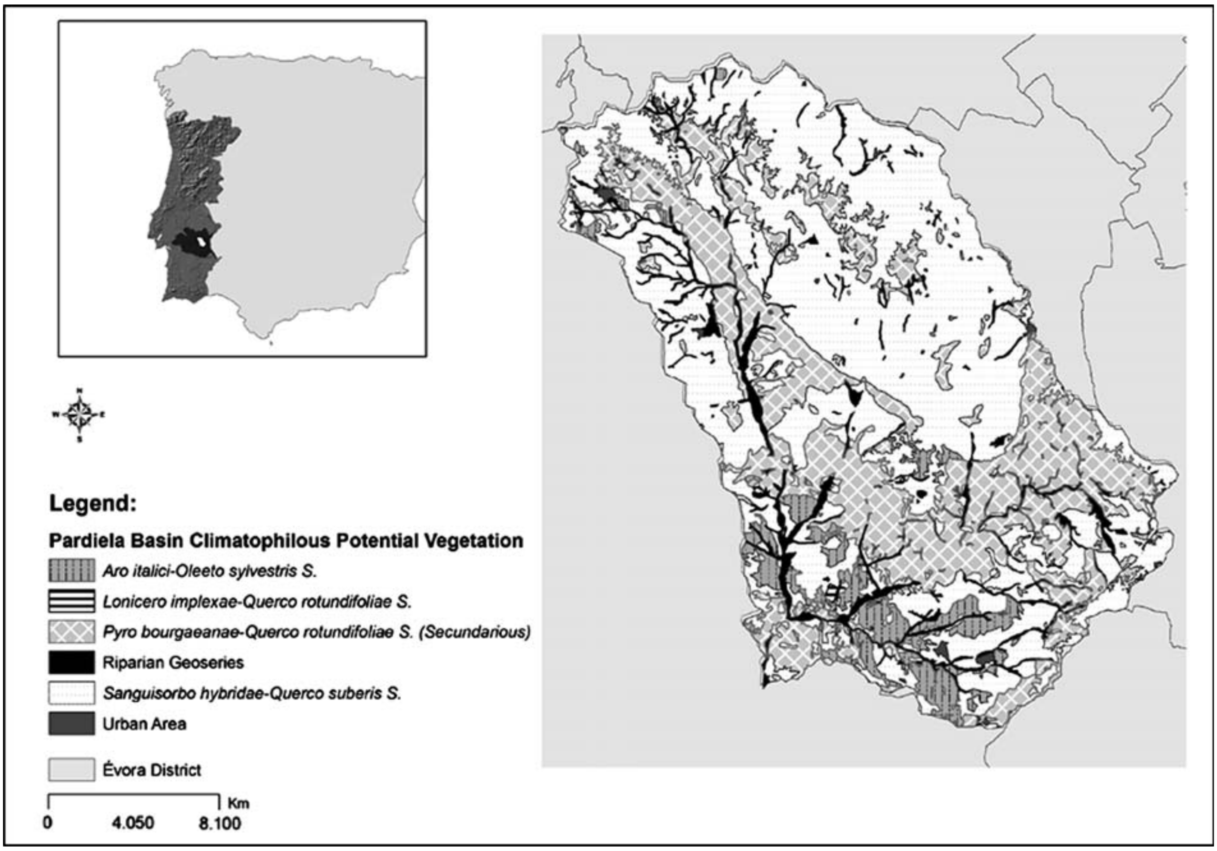

Figure 4. Pardiela Basin Potential Vegetation Map (Batista *et al.* forthcoming).
Figure 4. Carte de la végétation potentielle de la Bassin de la Rivière Pardiela.

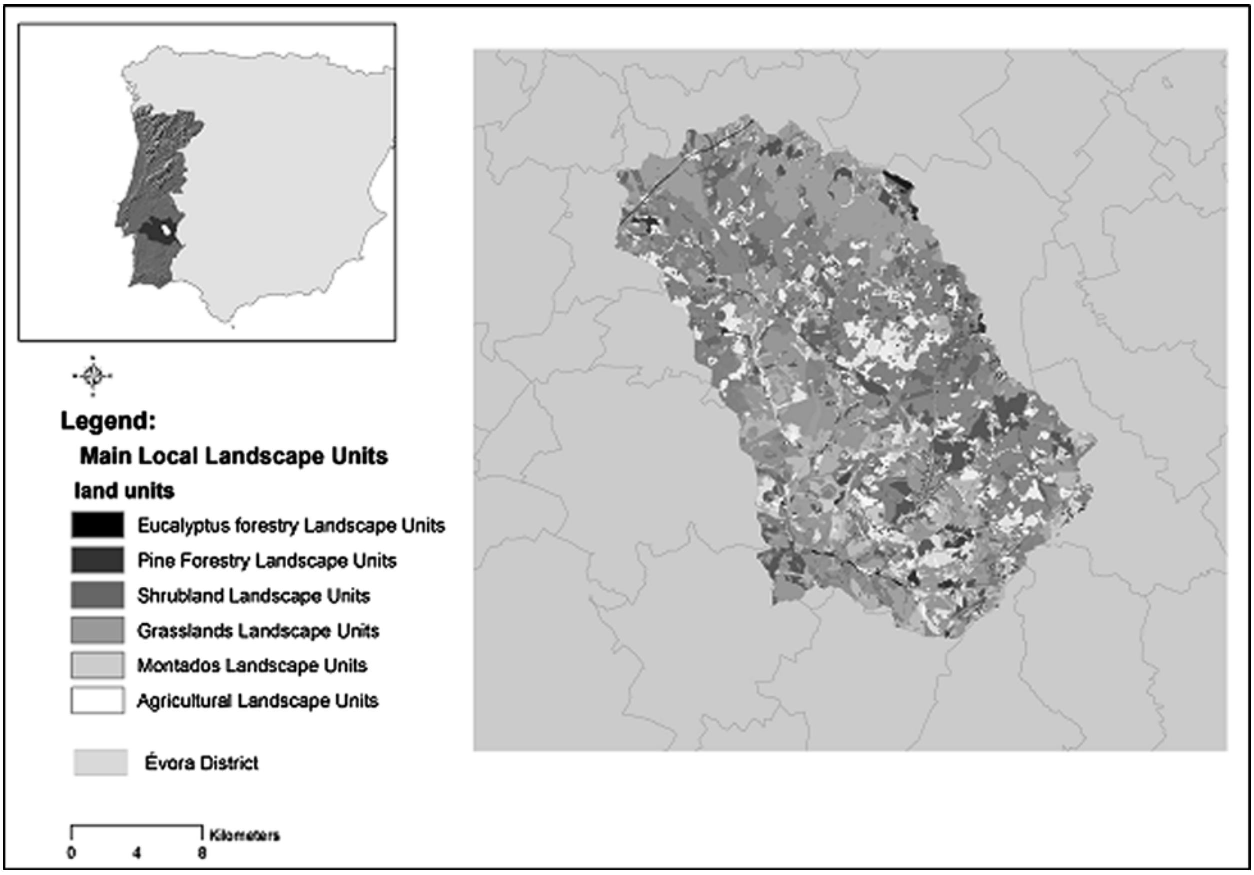

Figure 5. Pardiela Basin; Local Landscape Units.
Figure 5. Unités Locales du paysage de la Bassin de la Rivière Pardiela.

With the aggregation function these units have been joined together, and as a result it is possible to unify the territory, giving a better balance to the Cancela d'Abreu Land Units. The result relies on the existence of four distinct areas, coincident with Cancela d'Abreu, Pinto-Correia and Oliveira (2002) Landscape Units.

Comparing LLU with the potential vegetation map it is possible to verify some relationships between them. The agriculture LLU on the basin's extreme southwest, belong to *Aro italici-Oleeto sylvestris* S., which seems sensible, as they lie within the best soils (limestones) for agriculture in Central Alentejo.

All the *Montado* LLU (71 units) are on *Pyro bourgaeanae-Querco rotundifoliae* S. (Secundarious) and *Sanguisorbo hybridae-Querco suberis* S., which corresponds to the human transformation of autochthonous holm oak and cork oak forests by tree and shrub clearing and also by land ploughing to maintain open areas for livestock grazing, which leads to a unique type of wood pasture, the Spanish *dehesas* and Portuguese *montados* (Pulido, Diaz and Hidalgo De Trucios 2001).

Conclusions

Despite being carried out on a different scale LLU match the Cancela d'Abreu Land Units. The aggregation function allowed a better comparative analysis, mainly using approximated analysis scales. The potential vegetation map describes the relationship between the territory vegetation features, giving strength to LLU methodology. The LLU could be important tools in urban and landscape planning, providing a territorial holistic integrated view. In future studies, this methodology should be extended to Central Alentejo.

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