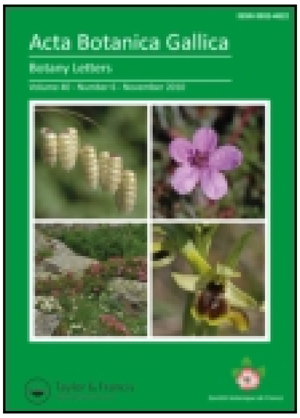

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Conservation status of vegetation in the North and Central area of Pardiela river basin (Évora, Portugal)

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Conservation status of vegetation in the North and Central area of Pardiela river basin (Évora, Portugal)

L'état de conservation de la végétation au nord et centre du bassin de la rivière Pardiela

Teresa Batista[a]*, Joana Cavaco[a], Paula Mendes[a], Carlos Vila-Viçosa[a], Ángel Penas[b], Sara del Río[b], José Cabezas[c], Luis Fernández-Pozo[c], Natália Arancibia[c] and Carlos Pinto-Gomes[a]

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Abstract: Pardiela's stream watershed was selected for a preliminary test of an ecological assessment through the application of the Potentiality Distance Index (PDI) methodology, based on current and potential vegetation maps. This analysis reveals the distance of a given vegetation community from its optimal potential state (climax) and the final PDI values portray the conservation status of the territory and allow the sketching of its needs for recovery or protection. Hence, territory management policies can subsequently be adjusted for better land use and biodiversity conservation. For this reason, this methodology can be an important step for landscape planning because it allows the adjustment of development proposals and activity monitoring. The final PDI value for the study area is 0.2509, indicating that Pardiela's basin conservation status is moderate.

Keywords: biodiversity conservation; ecological assessment; mapping; phytosociology; potential vegetation; Potentiality Distance Index

Résumé: Le bassin versant du ruisseau de la Pardiela a été sélectionné pour l'essai préliminaire d'une évaluation écologique par l'application de l'Index de Distance au Potentiel (PDI), basée sur les cartes de la végétation actuelle et potentielle. Cette analyse établit la distance d'une communauté végétale à son état optimal potentiel (climax) et les valeurs finales du PDI illustre l'état de conservation du territoire et permettre l'estimation de ses besoins en matière de valorisation ou de protection. Par conséquence, les politiques de gestion du territoire peuvent désormais être ajustées pour une meilleure utilisation du sol et la conservation de la biodiversité. Nous considérons cette méthode comme une étape essentielle pour un meilleur aménagement du paysage, car il permet l'ajustement des propositions de développement et la surveillance des activités. La valeur finale du PDI pour la zone d'étude est 0.2509, indiquant d'un état de conservation modérée.

Mots clés: conservation de la biodiversité; évaluation écologique; Index de Distance au Potentiel; phytosociologie; végétation potentielle

Introduction

Evaluating natural areas is a complex process that involves numerous factors and is therefore prone to be discredited by political interests. Each logical analysis of these factors using formulae and objective methodologies of quantification brings knowledge into environmental policy decision making, helping planning authorities to clarify their choices. Studies that contribute to this improving scenery include Lucas (1973), Nef (1977, 1981), Froment (1981), Arnáiz (1981), Báscones and Ursúa (1988), Dumort (1988), Boullet (1988), Delpech and Philippe (1988), Stein (1988), Onaníndia, Benito and García (1988), Bou i Tomas (1988), Géhu (1979, 1981, 1988, 1991, 1992), Géhu and Géhu-Frank (1979, 1981, 1988, 1991), Theurillat, Delarza and Werner (1988), Costa, Pérez and Sorano (1988), Martín and Asensi (1988), Asensi (1990), Asensi et al. (1991a,b, 1997), Meaza and Ormaetxea (1993), Sesma and Loidi (1993); Cano et al. (1994), Loidi (1994), Izco (1994), Díaz González *et al*. (1996a, 1996b), Díaz González and Fernández Prieto (1997), García-Baquero and Valle Gutiérrez (1998), Cadiñanos and Meaza (1998), Giménez

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Figure 1. Location of the study area in Continental Portugal and in Évora administrative district.
Figure 1. Localisation de la zone d'étude au Portugal continental et à Evora dans le quartier administratif.

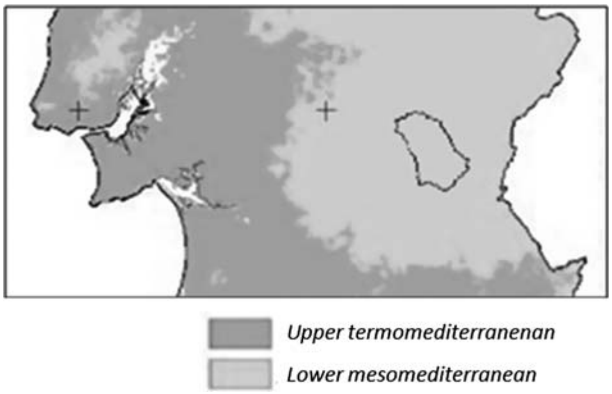

Figure 2. Location of the study area in the thermotypes map of Continental Portugal (Mesquita 2005).
Figure 2. Localisation de la zone d'étude dans la carte des thermotypes du Portugal Continental (Mesquita 2005).

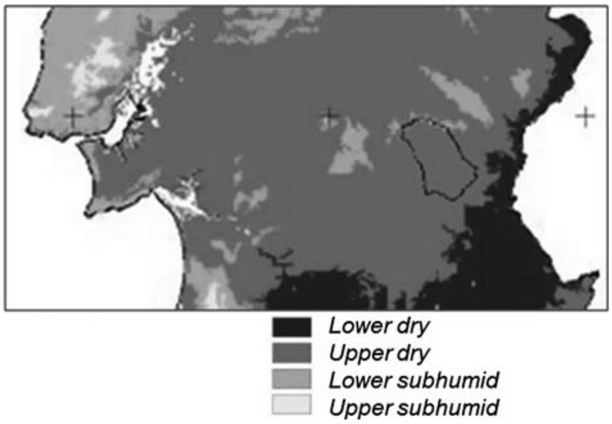

Figure 3. Location of the study area in the ombrotypes map of Continental Portugal (Mesquita 2005).
Figure 3. Localisation de la zone d'étude dans la carte des ombrotypes du Portugal Continental (Mesquita, 2005).

and Gómez (1999), Díaz González and García-Rodriguéz (2001), Penas, del Río and Herrera (2005, 2010).

After the thorough analysis of the mentioned indices the method chosen for the development of this study was the Potentiality Distance Index (PDI) proposed by Penas, del Río and Herrera (2005). According to the PDI, the level of maturity or degradation of the ecosystem is classified based on the position of each vegetal community in the succession process and the anthropic influence. The final value allows a clear and impartial comparison between different areas, useful for landscape planning studies and as base information for decision makers.

The chosen area for this preliminary test is the watershed of the Pardiela stream, because it holds a good sample of the most common land use and soil occupation in the region of Alentejo. This area is located in Portugal, in the Alentejo Central region and occupies part of the administrative limits of the municipalities of Évora, Alandroal, Redondo and Estremoz (Figure 1).

This territory is dominated by a gentle relief, which changes into corrugated relief in the approach to Serra de Ossa, located in the north of the area. The landscape has an overall presence of extensive dry land arable systems and is gradually transformed into a landscape structured by smaller properties with market gardens, vineyards, orchards and groves, close to small urban areas. In Serra de Ossa a greater change in land use occurred. It was wooded with eucalyptus and pine trees, resulting in the loss of biodiversity in this area (Cancela d'Abreu, Pinto Correira and Oliveira 2004).

Table 1. Field form data.
Tableau 1. Donnés à registrer dans les enquêtes.

1	**Polygon identification**: Serial number; Altitude; Slope; Exposure
2	**Geology and soil**: Geological structure; Soil type; Soil erosion level; Presence of hydromorphic soils vegetation indicators; Type of hydromorphism observed
3	**Land occupation and use**: Confirmation of CLC5 land cover class; Land use; Livestock type; Disturbance caused by livestock
4	**Biodiversity conservation**: Habitat Natura 2000; Conservation status
5	**Degradation factors**
6	**Fire indicators**: Combustibility degree; Inflammability degree
7	**Land cover**: Land cover description (Percentage of vegetation coverage per layer; Maximum height per layer; Vegetable communities observed per layer; Layer percentage occupied per community); Floristic elements; Vegetation series observed (Percentage of the polygon area occupied by each series; Succession stages observed per vegetation series; Percentage of the series area occupied by each succession stage; Naturalness Index for each succession community)
8	**Landscape detail observations**: Landscape typology; Polygon shape; Patches description (Type and shape of patch; Object distribution inside the patch); Corridor (Coherence, type, and object distribution inside the corridor); Matrix; Connectivity; Complementarity

Table 2. P_i and n assignment according to Penas, del Rio and Herrero (2005).
Tableau 2. Attribution des valeurs du P_i and n selon Penas, del Rio and Herrero (2005)

P_i	Succession stages
1	Most mature stage
↓	
n	Most depleted stage

P_i = Plant community succession stage in order of the total number of succession stages in the correspondent series of vegetation; n = Total number of succession stages of the series of vegetation. If the potential vegetation unity is a permasigmetum then $n = 1$.

Table 3. Naturalness Index evaluation criteria (Penas, del Rio and Herrero 2005).
Tableau 3. Critères d'évaluation de l'Index de Naturalité (Penas, del Rio and Herrero 2005).

Naturalness Index (NI)		
1	Low	For plant communities with a poor natural conservation status and strong human influence (distance from an optimum status over 50%)
2	Medium	For plant communities with a medium natural conservation status and some human influence (distance from an optimum status between 30% and 50%)
3	High	For plant communities with a high natural conservation status and low or none human influence (distance from an optimum status under 30%)

Biogeographically this area belongs to the Marianic-Monchiquensean Sector in the Lusitan-Extremadurean Subprovince of the Mediterranean West Iberian Province in the Western Mediterranean Subregion of the Mediterranean Region in the Holarctic Kingdom (Rivas-Martínez 2007).

Table 4. Potentiality Distance Index (PDI) evaluation criteria according to Penas, del Rio and Herrero (2005).
Tableau 4. Critères d'évaluation de l'index de Distance au Potentiel (PDI) selon Penas, del Rio and Herrero (2005)

PDI	Distance to the mature stage (DI)	Conservation state
0–0.25	Very distant	Low
0.26–0.50	Distant	Moderate
0.50–0.75	Approximate	Good
0.76–1	Proximal	Very good

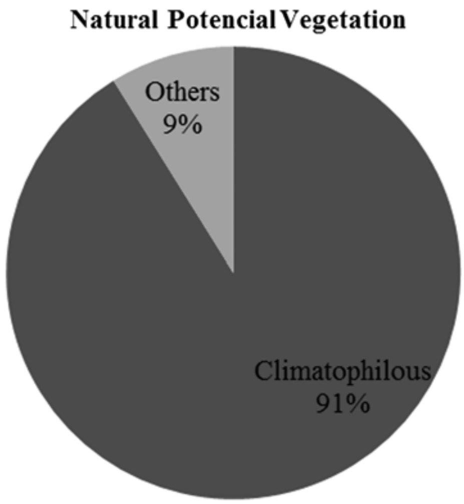

Figure 4. Balance between climatophilous and non-climatophilous vegetation series.
Figure 4. Différence entre la distribution des séries de végétation climathopyles et non-climathopyles.

The bioclimatic context of the territory where this area lies is the steppic variant of the Mediterranean pluviseasonal oceanic bioclimate (Rivas-Martínez 2007), more specifically in the lower mesomediterranean thermotype with a strong oceanic influence and upper dry ombrotype (Mesquita 2005; Figures 2 and 3).

Table 5. Area percentage per potential vegetation unit.
Tableau 5. Aire relatif par unité de végétation potentiel.

Natural Potential Vegetation	Area (%)
Sanguisorbo hybridae-Quercetum suberis S.	91,1521%
Ranunculo ficarioidis-Fraxino angustifoliae S.	2,6546%
Polygono equisetiformis-Tamaricetum africanae S.	0,2464%
Salicetum atrocinereo-australis S.	0,0453%
Oenantho crocatae-Nerietum oleandri S.	0,0109%
Callitrichio stagnalis-Ranunculetum saniculifolii permasigmetum	0,0942%
Glycerio declinatae-Oenanthetum crocatae permasigmetum	0,3197%
Digitali thapsi-Dianthetum lusitani permasigmetum	0,0026%
Gaudinio fragilis-Agrostietum castellanae permasigmetum	5,4305%
Thypho angustifoliae-Phragmitetum australis permasigmetum	0,0436%

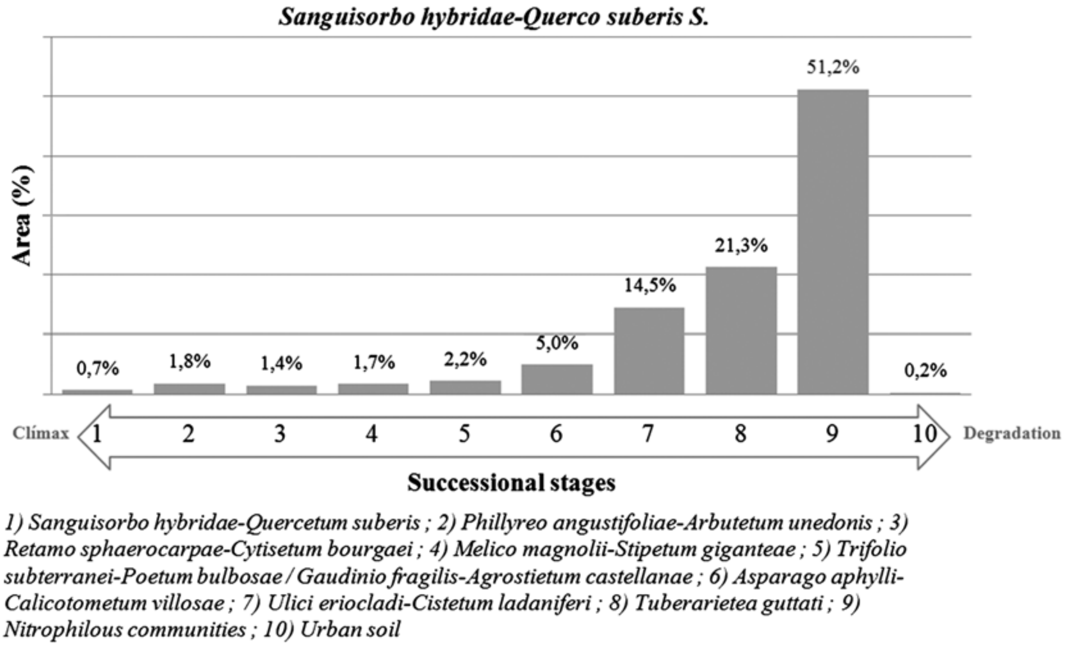

Figure 5. Communities distribution per succession stage in the *Sanguisorbo hybridae-Querco suberis* S.
Figure 5. Répartition par stade de succession des communautés constituantes de la série de végétation *Sanguisorbo hybridae-Querco suberis* S.

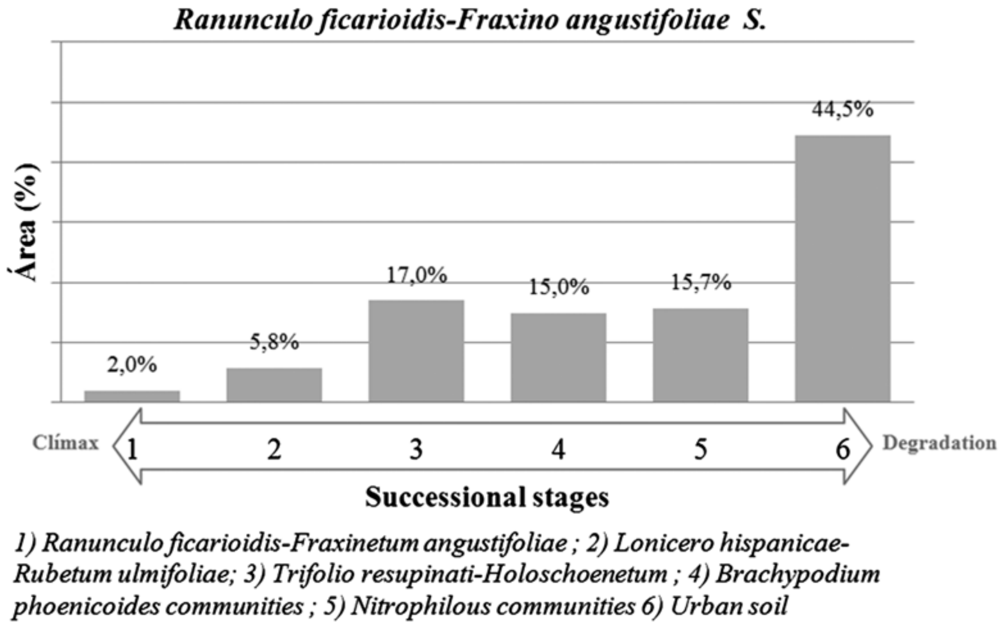

Figure 6. Communities distribution per succession stage in the *Ranunculo ficarioidis-Fraxino angustifoliae* S.
Figure 6. Répartition par stade de succession des communautés constituantes de la série de végétation *Ranunculo ficarioidis-Fraxino angustifoliae* S.

Material and methods

The first step of the methodology was an inventory, which led to selection of the significant landscape and vegetable indicators to observe, followed by definition of the analysis scales, measurement methods (ordinal scales) and evaluation criteria (qualitative indices). The data range gathered in the field is described in Table 1.

For the registry, update, storage and coherence verification of the information collected, two files were built: a database in Microsoft Office Access® with filling forms and a Microsoft Office Excel® file for the automatic analysis. Pardiela's stream landscape characterization was illustrated through digital maps made with ArcGis® 9.3.1 showing geomorphology, phytosociology, land cover,

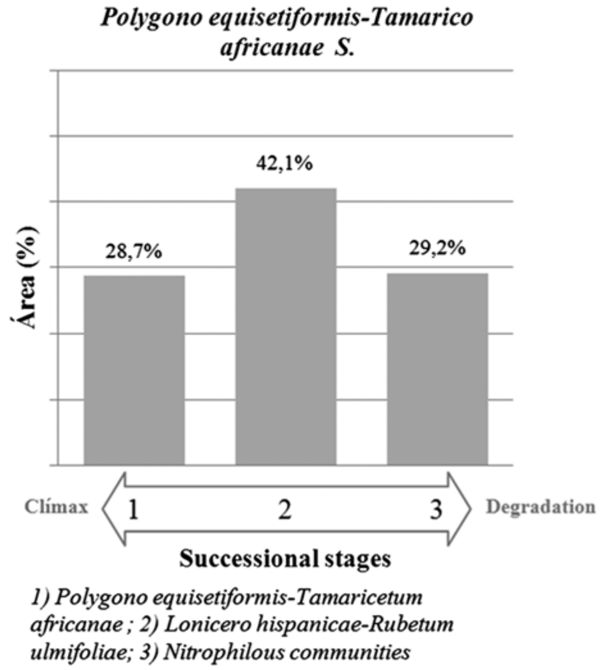

Figure 7. Communities distribution per succession stage in the *Polygono equisetiformis-Tamarico africanae* S.
Figure 7. Répartition par stade de succession des communautés constituantes de la série de végétation *Polygono equisetiformis-Tamarico africanae* S.

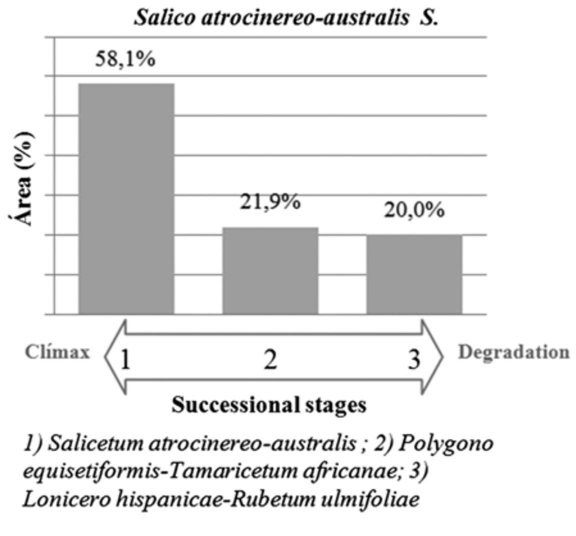

Figure 8. Communities distribution per succession stage in the *Salico atrocinereo-australis* S.
Figure 8. Répartition par stade de succession des communautés constituantes de la série de végétation *Salico atrocinereo-australis* S.

land use and newly modelled landscape units. The cartographic base was the Corine Land Cover map with a hierarchical CLC5 legend by Guiomar *et al*. (2006, 2009), at scale 1 : 10,000 (Batista 2012). It was also verified *in situ* if polygons of the Corine Land Cover map correspond to the reality observed in the field.

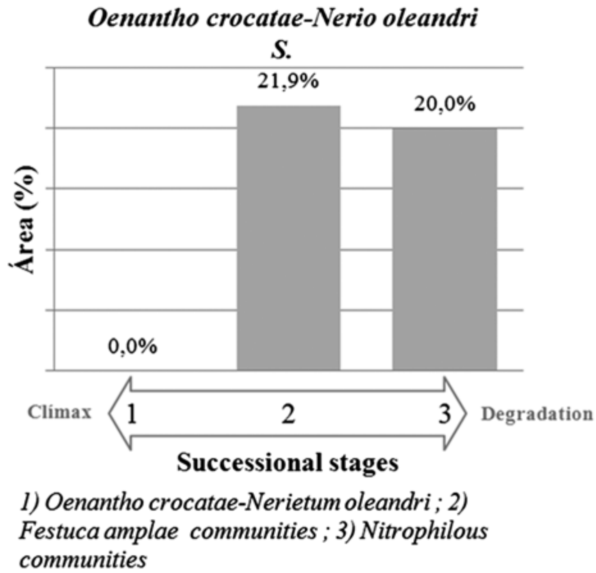

Figure 9. Communities distribution per succession stage in the *Oenantho crocatae-Nerio oleandri* S.
Figure 9. Répartition par stade de succession des communautés constituantes de la série de végétation *Oenantho crocatae-Nerio oleandri* S.

The data registered *in situ* regarding PDI evaluation were chosen based on phytosociological criteria (Rivas-Martínez et al. 2002) as a methodological basis, such as Penas, del Río and Herrero (2005) require. The biogeographic and bioclimatic characterization was made according to Rivas-Martínez (2007). All vegetation analysis was performed following the Zürich-Montpellier or Sigmatist Phytosociology School (Braun-Blanquet 1965; Rivas-Martínez 1976; Géhu and Rivas-Martínez 1981). For the identification of flora these were some of the references used: Coutinho (1939); Franco (1971-1984); Castroviejo et al. (1986–2010); Franco and Rocha-Afonso (1994–2003); Garmendia, Paiva and Villar (1986); Rivas-Martínez et al. (2001).

Each vegetation series dynamic has a specific number of succession communities – succession stages (Table 2) – to which this PDI methodology adds two more that represent the most disturbed and humanized stages: nitrophilous communities and urban soil. For each Corine Land Cover map polygon the following data were registered *in situ*:

- potential vegetation units observed;
- communities observed per sigmetum and the area occupied by it;
- Naturalness Index (NI) per community according to Penas, del Río and Herrera (2005) (Table 3).

These data were used to first calculate the distance to the most mature succession stage for each community, through the following equation (Penas, del Río and Herrera 2005):

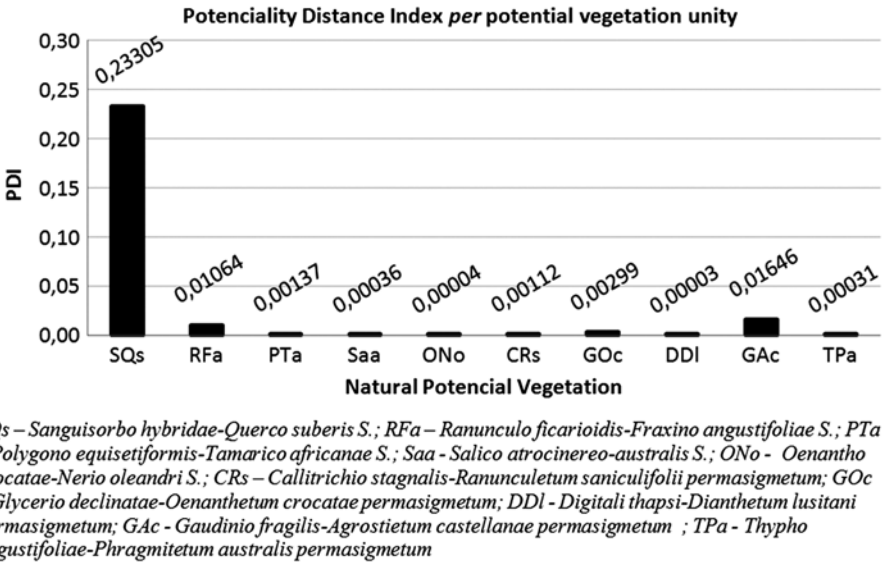

Figure 10. Potentiality Distance Index (PDI) per potential vegetation unit.
Figure 10. L'index de Distance au Potentiel (PDI) par unité végétal potentiel.

Table 6. Reference D_i values for each possible *NI* per succession stage for all the potential vegetation units present in Pardiela territory.
Tableau 6. Valeur de D_i pour possibilité de *NI* par communauté de succession pour toutes les unités de végétation do territoire de Pardiela.

	NI	*SQs* (n = 10) Di	*Rfa* (n = 6) Di	*Saa; PTa; ONo* (n = 3) Di	*GAc; DDl; GOc; CRs; TPa* (n = 1) Di
P_i = 1	3	1.00	1.00	1.00	1.00
	2	0.97	0.94	0.89	0.67
	1	0.93	0.89	0.78	0.33
P_i = 2	3	0.90	0.83	0.67	
	2	0.87	0.78	0.56	
	1	0.83	0.72	0.44	
P_i = 3	3	0.80	0.67	0.33	
	2	0.77	0.61	0.22	
	1	0.73	0.56	0.11	
P_i = 4	3	0.70	0.50		
	2	0.67	0.44		
	1	0.63	0.39		
P_i = 5	3	0.60	0.33		
	2	0.57	0.28		
	1	0.53	0.22		
P_i = 6	3	0.50	0.17		
	2	0.47	0.11		
	1	0.43	0.06		
P_i = 7	3	0.40			
	2	0.37			
	1	0.33			
P_i = 8	3	0.30			
	2	0.27			
	1	0.23			
P_i = 9	3	0.20			
	2	0.17			
	1	0.13			
P_i = 10	3	0.10			
	2	0.07			
	1	0.03			

SQs, *Sanguisorbo hybridae-Querco suberis* S.; *Rfa*, *Ranunculo ficarioidis-Fraxino angustifoliae* S.; *Pta*, *Polygono equisetiformis-Tamarico africanae* S.;*Ono*, *Oenantho crocatae-Nerio oleandri* S.; *Saa*, *Salico atrocinereo-australis* S.; *CRs*, *Callitrichio stagnalis-Ranunculetum saniculifolii permasigmetum*; *Goc*, *Glycerio declinatae-Oenanthetum crocatae permasigmetum*; *DDl*, *Digitali thapsi-Dianthetum lusitani permasigmetum*; *Gac*, *Gaudinio fragilis-Agrostietum castellanae permasigmetum*; *Tpa*, *Thypho angustifoliae-Phragmitetum australis permasigmetum*. DI_i, Plant community distance to the most mature succession stage; NI, Community's Naturalness Index.

$$DI_i = 1 - \left(\frac{3P_i - N_i}{3n}\right) \quad (1)$$

where DI_i is the plant community distance to the most mature succession stage, *i* is the plant community analysed; P_i is the plant community succession stage in order of the total number of succession stages in the correspondent vegetation series; NI_i is the community's Naturalness Index, and *n* is the total number of succession stages of the vegetation series.

Once this value is known we can fully calculate the PDI value for the area with another formula (Penas, del Río and Herrera 2005):

$$PDI = \sum_{i=1}^{n} DI_i \times \frac{\Omega_i}{\Omega_{total}} \quad (2)$$

where Ω_i is the plant community area and Ω_{total} is the total study area.

The calculation of the PDI permitted the identification of areas with a greater need for recovery or protection (Table 4). The correlation between these areas and the remainder of the polygon information gathered *in situ* led to the identification of general causes of area decay.

Results and discussion

The field surveys allowed the collection of valuable information for further studies in this area, as well as for the actualization and validation of the land cover map. This study identified 10 different potential vegetation units within the territory of the Pardiela stream watershed. *Sanguisorbo hybridae-Querco suberis* S. covers the majority of the area with a presence of 91% against 9% of the remaining vegetation units (Figure 4). *Sanguisorbo hybridae-Querco suberis* S. is a climatophilous vegetation series. The remaining non-climatophilous vegetation units observed were rupicolous, hygrophilous or mesohygrophilous. Their small percentage was a result of a linear and scattered distribution of habitats with a subsequently inferior area (Table 5).

The *Sanguisorbo hybridae-Querco suberis* S. has 10 vegetation communities (one climax; seven succession stages; two humanized) distributed as shown in Figure 5.

Considering edaphohygrophilous vegetation series, the *Ranunculo ficarioidis-Fraxino angustifoliae* S. is the most significant in the study area (Figure 6). Figures 7 to 9 **show the succession stages of *Polygono equisetiformis-Tamarico africanae S., Salico atrocinereo-australis S. and Oenantho crocatae-Nerio oleandri*** S.

There are also five permasigmetum present in Pardiela's watershed: *Callitrichio stagnalis-Ranunculetum saniculifolii; Glycerio declinatae-Oenanthetum crocatae; Thypho angustifoliae-Phragmitetum australis; Digitali thapsi-Dianthetum lusitani and Gaudinio fragilis-Agrostietum castellanae*. The first three are aquatic, the fourth is rupicolous and the fifth is mesohygrophilous.

Table 6 presents a synthesized overview of all the possible D_i values for every vegetation series and permasigmetum found in the study area. The PDI results for Pardiela are shown in Figure 9. The final PDI value for the Pardiela stream watershed is 0.2509. Although *Sanguisorbo hybridae-Querco suberis* S. shows the highest occupation area, only 0.7% of that area is at the climax stage. This means that the Pardiela basin is distant from its series head and therefore its conservation status is moderate.

Conclusion

Pardiela's watershed is a landscape with a long history of humanization that led to soil impoverishment over the centuries caused by its use as pasture for livestock. The cultural heritage of Cork oak and Holm oak extensive systems has continued from ancient times, allowing adequate coexistence with those land uses because of the multifunctional nature of the *montado*.

The PDI results show a decreasing tendency towards the south of the watershed. The basin presents high soil exhaustion caused by intensive livestock grazing and agricultural soil use. The local topography allows intensive and mechanized methods and the smaller streams endure excessive grazing, leading to a decrease of the natural vegetation communities. The restoration of the natural vegetation communities could enhance PDI levels.

These results point out the unbalanced relation between economical activities and nature conservation; they demonstrate the need to rethink this landscape and carry out great changes in land cover management, with vegetation recovery and protection actions. The next steps will comprise: mapping of the most depleted areas, with greater risks and preservation needs; the identification of the degradation agents, analysing land owners' problems and difficulties in this area and their solutions; and the positive readjustment of legislation and planning mechanisms to the new requirements of the landscape and the people.

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