Ecological Factors Affecting Plant Communities' Distribution on International Tagus River Natural Park

Luís Quinta-Nova
Instituto Politécnico de Castelo Branco. Escola Superior Agrária, Quinta da Sr. de Mércules. 6001-909 Castelo Branco, Portugal, lnova@ipcb.pt

Alice Almeida
Instituto Politécnico de Castelo Branco. Escola Superior Agrária, Quinta da Sr. de Mércules. 6001-909 Castelo Branco, Portugal
Centro de Competências em Cloud Computing (C4-UBI), Universidade da Beira Interior, Rua Marquês d'Ávila e Bolama, 6201-001, Covilhã, Portugal.

João Carvalhinho
Instituto da Conservação da Natureza e das Florestas, I.P., Castelo Branco, Portugal

Abstract: Straddling the frontiers of two neighboring countries around the Tagus River, Portugal and Spain, the International Tagus River Natural Park (ITRNP) extends over an area of 26,484 hectares in the district of Castelo Branco, Portugal. The vegetation of the Park is mainly typical of Mediterranean ecosystems, such as cork oak and holm oak, Mediterranean evergreen scrubland with strawberry tree, kerms oak, terebinth, mock privet, and mastic; thermophilic formations of rockrose, lavender and broom; bush formations, more or less open with olive and wild olive trees; and riparian vegetation, emphasizing the bushweed formations and the galleries of willow trees. In this territory, 726 taxa distributed by 98 botanical families have been identified to date, emphasizing the 51 endemic species detected. In terms of protected Flora the ITRNP the Portuguese endemisms *Festuca duriotagana* and *Linaria amethystea* subsp. *multipunctata*. There are also 41 Iberian endemisms. A study was conducted in the ITRNP to provide insight into the main factors affecting the different plant communities' distribution in the region, and to provide recommendations for the selection of indigenous species in order to monitor the succession process of vegetation in areas affected by wildfires. The study was conducted in sites evenly distributed in the area of ITRNP representing homogeneous vegetation types, the floristic composition and cover of the species were determined in 188 floristic inventories. During the study period, a total of 249 species were recorded. Cluster analysis identified 12 main vegetation communities. The sites were ecologically characterized, at a local scale, using environmental data as bioclimatology, lithology, topography, soil type and its physical and chemical composition. The role of those environmental factors in the explanation of vegetation variation was assessed using canonical correspondence analysis (CCA). Geostatistics tools were also used to interpolate the species distribution and the community diversity index.

Keywords: Plant conservation, Tagus river, protected area, spatial analysis

Introduction

Whether biological communities are deterministic or stochastic assemblages of species has long been a central topic of ecology (Grant & Abbott, 1980; Simberloff, 1981 and Drake, 1990). The widely demonstrated presence of structural patterns in nature may imply the existence of rules that regulate the ecological communities' organization (Colorado, 2015). Drake (1990) suggests that the consequence of the mechanism (e.g., coexistence, extinction, variation in ensemble properties and configurations) appears to be strongly dependent on historical context.

The abiotic environment influences community assembly by restricting which species can be established at the site and by constraining the function of successful colonists (Belyea & Lancaster, 1999; Booth & Swanton, 2002). On the other hand, environmental constraints are assumed to remain constant for long enough that communities approach equilibrium and the outcome of many assembly rules that are resource-based is more likely to be detected (Colorado, 2015). Hence, environmental constraints influence species interactions and the expression of assembly rules related with the availability of space, energy and nutrients (Belyea and Lancaster, 1999).

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To study the underlying mechanisms driving the assembly of plant species in natural communities is critical for understanding the uneven distribution and the patterns of plant diversity (Gotelli & McCabe, 2002). Among the main deterministic factors, abiotic conditions and plant-plant interactions play crucial roles in determining species co-occurrence and abundance distributions in plant communities. Abiotic variations are well known characteristics which affect plant communities and populations (Khan et al., 2017). These factors contribute to understand distribution, composition and diversity of plant communities (Brown, 1984). Variations in latitude and altitude lead to changes in air temperature, and humidity that then affect the plant species composition and the community structure (Xu et al., 2017).

Daget et al. (1993) refer that the climatic factors that control the vegetation pattern are: global humidity; winter thermal intensity and seasonal thermal contrast (oceanity vs. continentality). Rivas- Martínez (2001) concluded that seasonal thermal contrast is the most important factor that operates in the distribution of vegetation. At a local scale, climate is affected by topography such as slope, elevation and aspect, in addition to affect of evapotranspiration and temperature (Khan et al., 2017).

Temperature and precipitation stand out as the most direct responsible for the distribution of ecosystems on Earth (Rivas-Martínez, 1987). In areas subject to Mediterranean macroclimatic conditions, like the study area, there is always summer aridity with at least two months of drought (Rivas-Martínez, 1996). The water balance is considered as the main conditioning factor for vegetation, and the structure of the Mediterranean vegetation assumes very different types, from closed deciduous or perennial forests, to open forests and scrub, depending on the amount of rainfall available (Costa-Tenorio et al., 1998). In terms of Bioclimatology the study area is under the thermomediterranean thermotype and dry ombrotype conditions.

Soil is also an important ecological limiting factor that determines plant growth, and is influenced by organisms, climate, topography, time and parent material (Hoveizeh, 1997). The Paleozoic substrates are the source of the two main soil units prevalent in the area, the Distric Cambisols and the Eutric Lithosols. The Cambisols appear in the granitic patches and are soils with a high permeability. Lithosols are incipient, without defined horizons, and are dominant in schist areas.

To study the relationships between environmental variables and plant species data researchers use multivariate approaches. The multivariate statistical analytical software assists the ecologists to analyze the effects of environmental factors on different species and to know the structure in the data set (Anderson et al., 2006). The aim of the current study is to identify the main environmental factors that influence the distribution of plant species and communities in the International Tagus River Natural Park (ITRNP) – a protected area that extends over an area of 26,484 hectares in the district of Castelo Branco, Portugal. To provide recommendations for the selection of indigenous species in order to monitor the succession process of vegetation in areas affected by wildfires inside the Natural Park is also an aim of this study.

Method

Site Description

The International Tagus Natural Park is a sanctuary of Nature located in Beira Baixa. Located at the southern end of the county of Castelo Branco and at the south and east end of the county of Idanha-a-Nova, the park corresponds to a strip of approximately 40 km near the river Tagus. The ITNP is an area of recognized importance in terms of nature conservation, for the value it holds for the fauna it contains and the various species strictly protected by international conventions.

The International Tagus Natural Park contains an important faunistic community, including more than two hundred species of vertebrates. The encased valleys of the Tagus and Erges rivers have a wild character that gives them appreciable scenic value. On certain slopes outcrops rise in the form of cliffs forming true rocky gorges like those observed, for example, of the Roman bridge of Segura. So far 179 species of birds have been inventoried in the ITNP. Also identified are 39 species of mammals, 17 species of reptiles, 13 amphibians, 21 fish, and more than 300 species of insects, of which 189 are butterflies. Among the mammals, the presence of the otter, the wild cat and the toad is outstanding.

In this territory, 726 taxa distributed by 98 botanical families have been identified to date, emphasizing the 51 endemic species detected. The ITNP presents communities typical of Mediterranean ecosystems, such as cork oak and holm oak, Mediterranean scrubland with holm oaks, strawberry trees, kerms oak, terebinths, mock privet and mastics, thermophilic formations of rockrose, lavander and broom, bush formations, more or less open with olive and wild olive trees, and vegetation of the lines of water, emphasizing the bushweed formations and the galleries of willow trees.

In terms of Flora, the Lusitanian endemisms *Dittrichia viscosa* subsp. *revoluta*, *Festuca duriotagana* var. *duriotagana*, *Linaria amethystea* subsp. *multipunctata*. There are also 41 Iberian endemisms.

Data Collection and Identification

Data collection took place between 2000 and 2003 and a total of 188 vegetation plots were recorded in all the extension of the territory of the International Tagus Natural Park (see Figure 1). The survey followed the Zurich–Montpellier method (Kent and Coker, 1994).

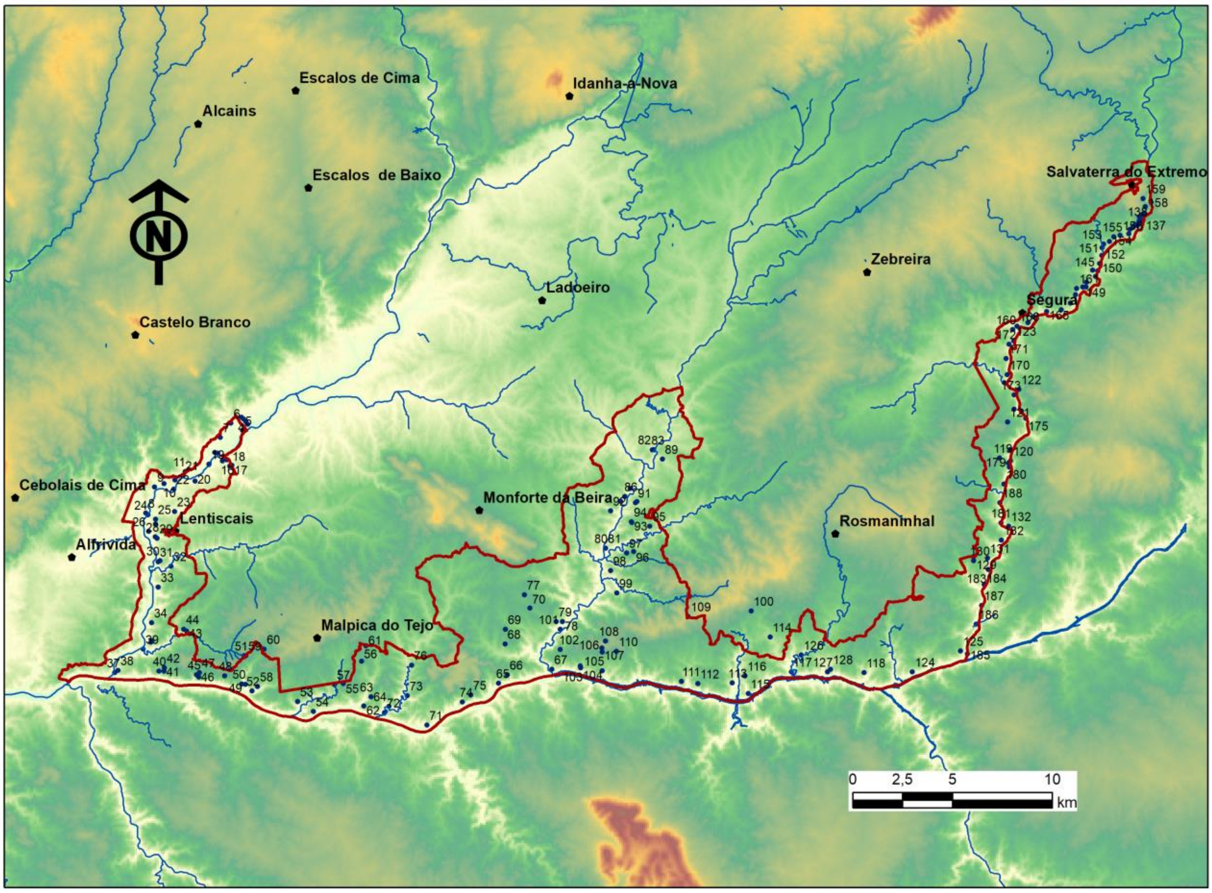


Figure 1. Location of the 188 studied Floristic Inventories

At least were collected 3 individuals of the same taxon, to which were given a code in order to relate with the site of collection. During the collection, was given preference to plants that had a phenology favourable to a correct identification. In laboratory, with the use of optical instruments and plant identification manuals all the collected plants were identified. The concept of minimal area, or the smallest area that represents a community, was applied (Kent & Coker, 1994).

Data Analysis

The obtained data of 188 floristic inventories were arranged in MS Excel for further analyses through Cluster analysis based on abundance classes of the 249 plant species identified.

Cluster analysis UPGMA was used in order to aggregate the main vegetation communities based in its species composition by clustering the sites corresponding to the vegetation plots based on the abundance of plant species.

A GIS data base was loaded with the abundance values of each plant species (249 fields) per sites (188 rows). ArcGIS 10.6 geostatistical tools were used to interpolate the species distribution and the Species Richness. The select method to interpolate a raster surface from a points theme (vegetation plots) was the inverse distance weighted (IDW) technique (Kent & Coker, 1994).

The species data was arranged in columns and sites in rows as per requirement of CANOCO version 5.0 (Šmilauer and Lepš, 2014). The environmental variables data were also arranged in columns and sites in rows in another table. A direct ordination technique - Canonical Correspondence Analysis (CCA) was used to find the influence of different environmental variables in 57 woody plant species presence and abundance.

A diagram was plotted showing the woody species ordered along the canonical axes representing the different environmental factors: Bioclimatology: Thermicity index (It) and Ombrothermic index (Io); Topography: Elevation, Slope and Aspect and Soil types (classification based in soil structure and texture, pH, % OM, % active Ca ($CaCO_3$) and C/N ratio).

Results and Discussion

Distribution Maps

Figure 2 represents the Species Richness distribution raster surface resulting from the interpolation using the inverse distance weighted (IDW) technique from the vegetation plots theme. The highest values of plant diversity are located in the NE part of the ITRNP, along the right bank of the Erges River. To those high Species Diversity values the herbaceous strata contributes strongly.

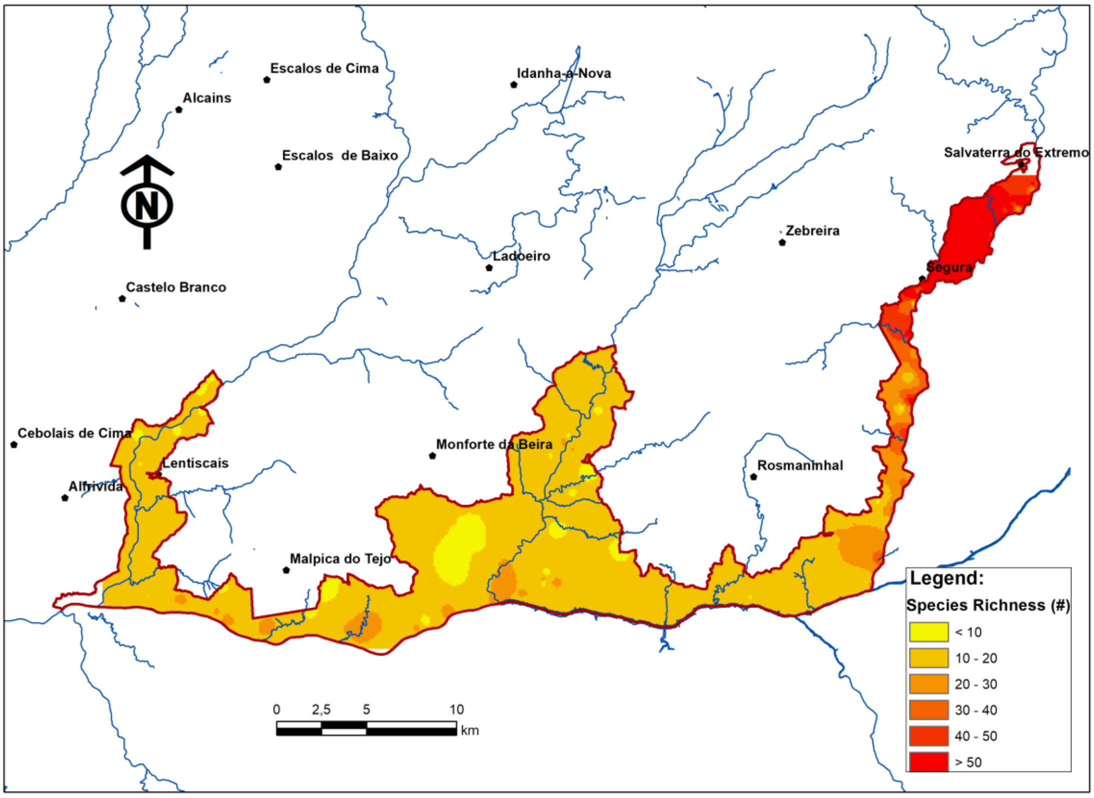
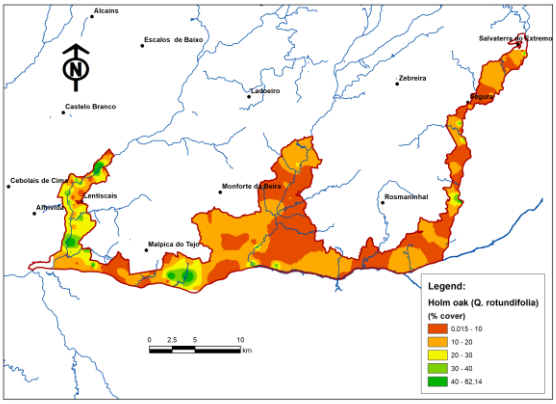
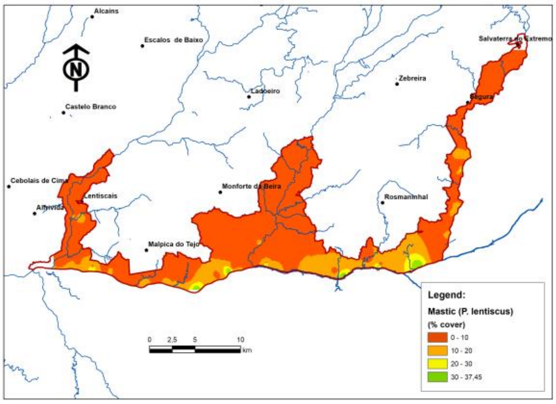


Figure 2. Plant Species Richness

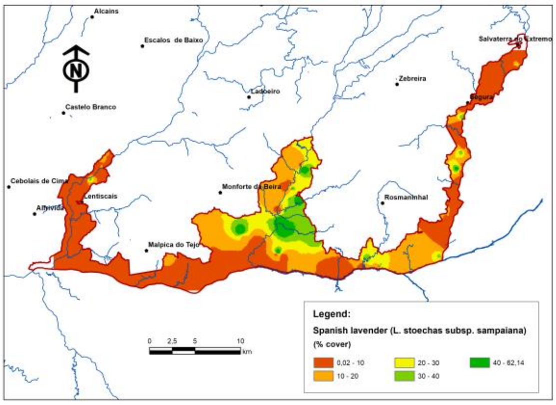
In Figure 3 a) to d) is showed the distribution of four of the most representative woody species, based in the vegetation plots theme, also using the inverse distance weighted (IDW) technique.



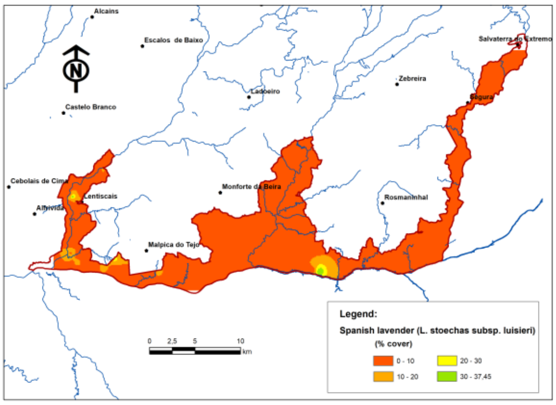
(a) *Quercus rotundifolia* - Holm oak



(b) *Pistacia lentiscus* - Mastic



(c) *Lavandula pedunculata* - French lavender



(d) *Lavandula stoechas* subsp. *luisieri* - Lavender

Figure 3. Distribution Maps of Some of the Most Representative Woody Species

Cluster Analysis

Cluster analysis established a clear separation of clusters, showed in Figure 4, with five distinctive plant communities identified from the vegetation plots:

Community 1: Different riparian vegetation types - (type 1) dominated by bushweed (*Fluggea tinctoria*), belonging to the community *Pyro bourgaeanae-Securinegetum tinctoriae*; (type 2) dominated by sage-leaved willow (*Salix salvifolia*), belonging to the community *Salicetum lambertiano-salvifoliae*;

Community 2: Natural grassland communities with a high diversity of herbaceous species, belonging to different communities like *Trifolio cherleri–Plantaginetum bellardii*, *Bromo tectorum-Stipetum capensis* and *Phagnalo saxatilis–Rumicetum indurate*;

Community 3: Low density holm oak forest (*Quercus rotundifolia*), belonging to the community *Pyro bourgaeanae-Quercetum rotundifoliae*;

Community 4: Scrubs frequently associated to low density holm oak areas, dominated by gum rockrose (*Cistus ladanifer*), belonging to the community *Genisto hirsutae-Cistetum ladaniferi*;

Community 5: Tall scrubs dominated by species like retama broom (*Lygos sphareocarpa*) and Portuguese broom (*Cytisus striatus*), belonging to the community *Cytiso multiflori-Retametum sphaerocarpae*.

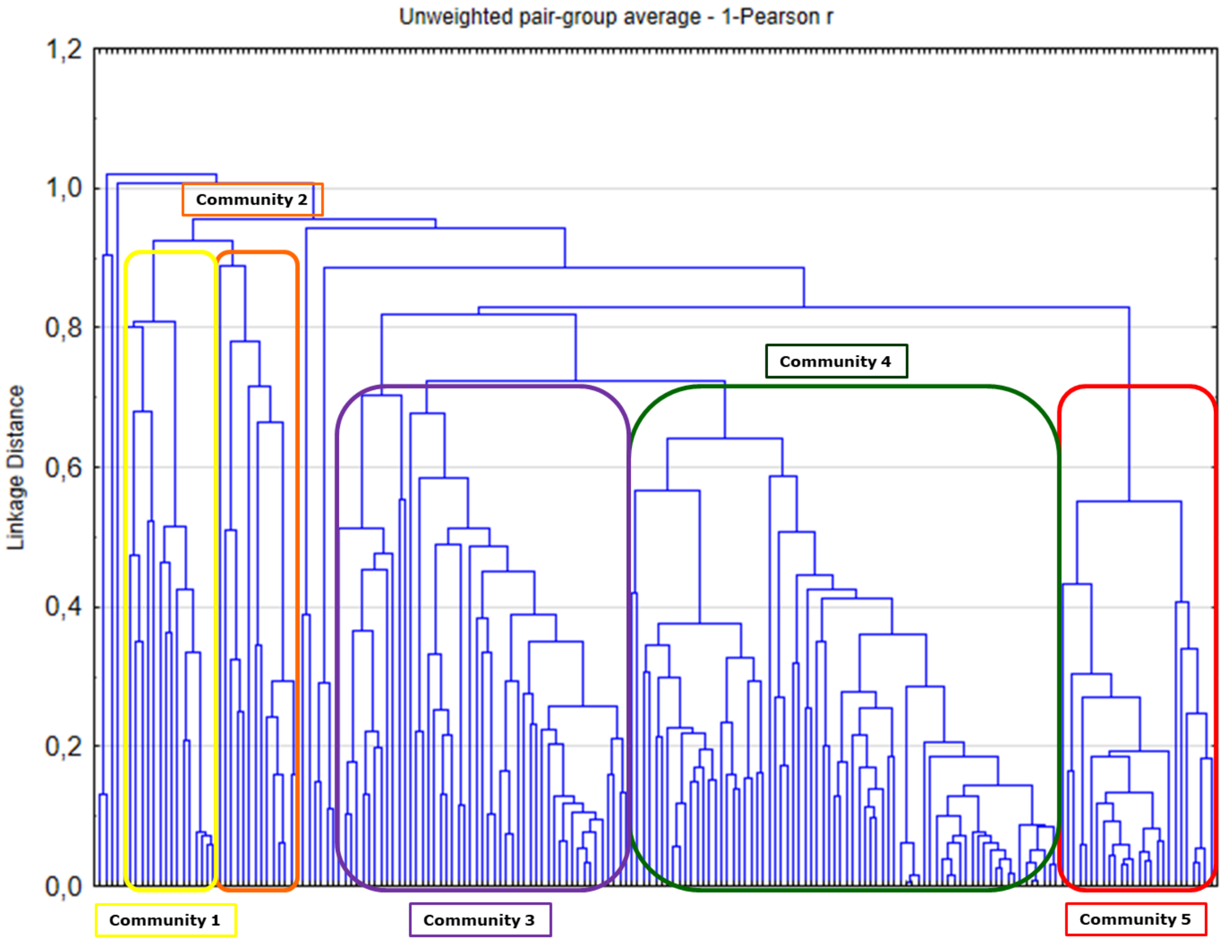


Figure 4. Cluster Dendrogram of 188 Plots Showing Plant Communities

Canonical Correspondence Analysis

The Monte Carlo permutation test showed that there was a significant correlation (P=0.002) between the five environmental variables and the ordination axes. The cumulative variance explained with the first two axes is 71,29% (Table 1).

Table 1. CCA Summary Table

Statistic	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalues	0.2709	0.1964	0.0912	0.0576
Explained variation (cumulative)	4.95	8.54	10.21	11.26
Pseudo-canonical correlation	0.7142	0.7398	0.6039	0.5355
Explained fitted variation (cumulative)	41.33	71.29	85.21	93.99

Through the interpretation of the explanatory variables axes of the CCA Biplot (Figure 5) it can be seen that the first axis is positively correlated with the Bioclimatology and Soil type. The variables that are positively correlated with the second axis are the topographic ones - Elevation and Aspect. In Table 2 are presented the legend of the plant species abbreviations. The most important environmental factors affecting the abundance of plant species in the ITRNP area were slope, elevation and soil type.

Species more commonly associated with high altitude areas furthest from the Tagus River include shrub species like *Chamaespartium tridentatum*, *Genista hirsuta* and *Genista triacanthos*. In steep areas the plant species more adapted to those conditions are *Arbutus unedo*, *Viburnum tinus* and *Cistus populifolius*.

The main parameter that separates species correlated with the environmental factor Soil type is the soil moisture. The plant species positively correlated with the Soil type have as habitat areas with high soil moisture located in river banks - riparian vegetation, like *Fluggea tinctoria*, *Alnus glutinosa*, *Fraxinus angustifolia*, *Salix salvifolia* and *Rubus ulmifolius*. The plant species negatively correlated with Soil type are associated to dryer soils like *Quercus rotundifolia* and *Olea europaea*.

In summary, CCA ordinations suggest that there are statistically significant relationships between plant species distributions and the selected environmental variables.

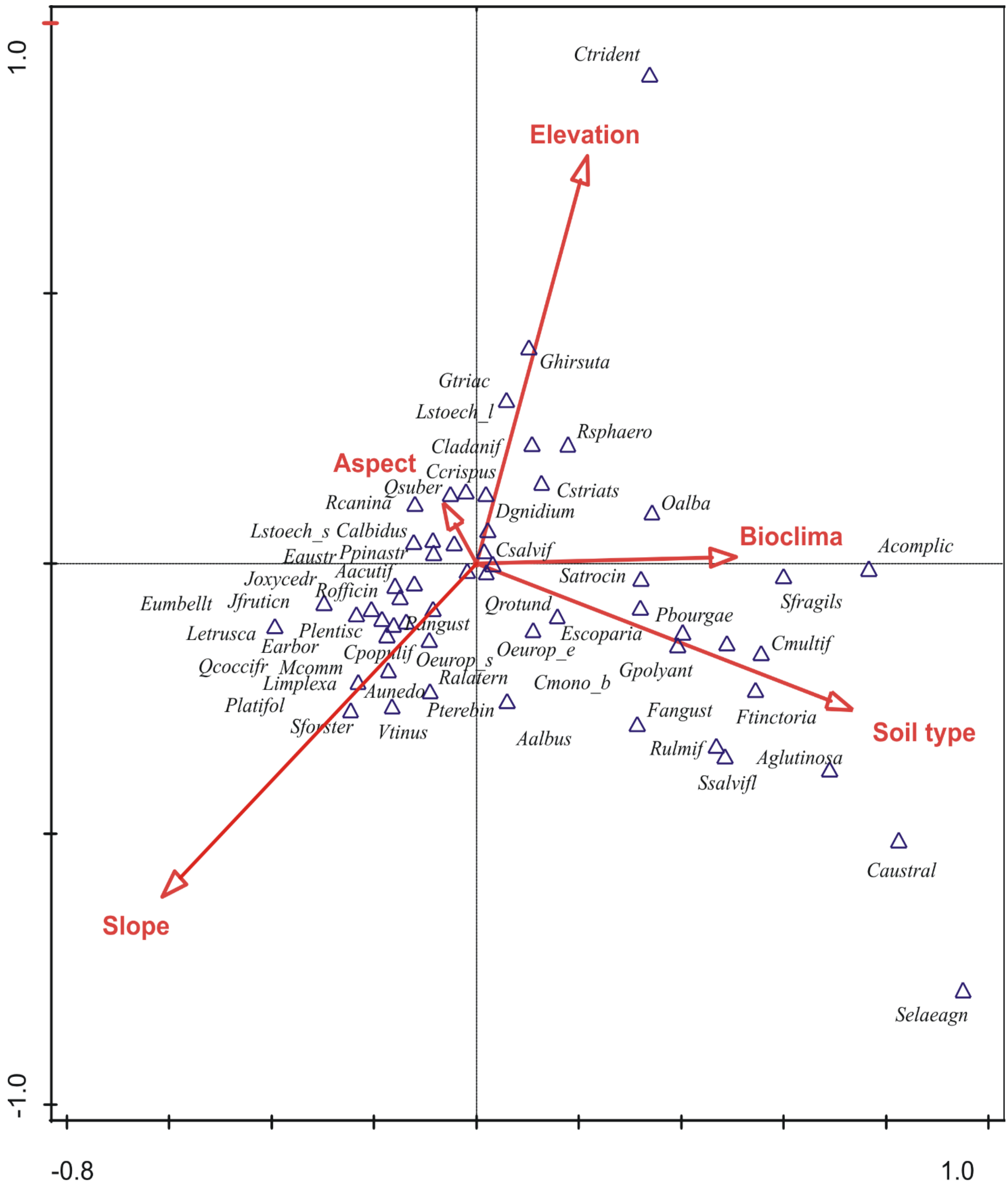


Figure 5. CCA Biplot

Table 2. Species Abbreviation used in CCA Biplot

Abbrev.	Scientific name	Abbrev.	Scientific name	Abbrev.	Scientific name
Aacutif	*Asparagus acutifolius*	Fangust	Fraxinus angustifolia	Platifolia	*Phillyrea latifolia*
Aalbus	*Asparagus albus*	Ftinctoria	Fluggea tinctoria	Plentiscus	*Pistacia lentiscus*
Acomplic_a	*Adenocarpus complicatus*	Ghirsuta	Genista hirsuta	Ppinaster	*Pinus pinaster*
Aglutinosa	*Alnus glutinosa*	Gpolyanth	Genista polyanthos	Pterebin	*Pistacia terebinthus*
Aunedo	*Arbutus unedo*	Gtriac	Genista triacanthos	Qcoccifera	*Quercus coccifera*
Caustralis	*Celtis australis*	Hocym	Halimium ocymoides	Qrotund	Quercus rotundifolia
Calbidus	*Cistus albidus*	Hviscosum	Halimium viscosum	Qsuber	Quercus suber
Ccrispus	*Cistus crispus*	Jfruticans	Jasminum fruticans	Ralaternus	Rhamnus alaternus
Cladanifer	*Cistus ladanifer*	Joxycedrus	Juniperus oxycedrus subsp. oxycedrus	Rcanina	Rosa canina
Cmono_b	*Crataegus monogyna* subsp. *brevispina*	Letrusca	*Lonicera etrusca*	Rofficin	Rosmarinus officinalis
Cmultif	*Cytisus multiflorus*	Limplexa	*Lonicera implexa*	Roleoides_f	Rhamnus oleoides subsp. fontqueri
Cpopulif	*Cistus populifolius*	Lstoechas_l	*Lavandula stoechas* subsp. *luisieri*	Rsphaero	Retama sphaerocarpa
Csalvif	*Cistus salvifolius*	Lstoechas_s	*Lavandula pedunculata*	Rulmif	Rubus ulmifolius
Cstriatus	*Cytisus striatus*	Mcomm	*Myrtus communis*	Satrocine	Salix atricinerea
Ctrident	*Chamaespartium tridentatum*	Oalba	*Osyris alba*	Selaeagnos	Salix elaeagnos
Dgnidium	Daphne gnidium	Oeurop_eur	*Olea europaea* var. *europaea*	Sforsteranum	Salix forsteranum
Earbor	Erica arborea	Oeurop_syl	*Olea europaea* var. *sylvestris*	Sfragilis	Salix fragilis
Eaustr	Erica australis	Pangust	*Phillyrea angustifolia*	Ssalvifolia	Salix salvifolia
Escopar_s	Erica scoparia subsp. scoparia	Pbourgae	*Pyrus bourgaeana*	Vtinus	Viburnum tinus
Eumbellata	Erica umbellata				

Conclusion

Primarily, this study will improve the understanding of the distribution and ecology of plant taxa in the International Tagus River Natural Park, and its results provide data that can be used as a baseline for monitoring change. The study results will be helpful to stakeholders in order to manage the natural and agroforest production areas inside the Natural Park and to provide recommendations for the selection of indigenous species in order to monitor the succession process of vegetation in areas affected by wildfires.

The combination of multivariate analysis and GIS gave important insights. The Cluster Analysis exposed five vegetation types, and can therefore be seen as useful tools in vegetation ecology studies. The CCA reveal that the environmental factor Slope, Elevation and Soil type are the most influential factors that explain the species distribution in ITRNP.

Recommendations

Further study on the factors that influence the distribution of plant species in ITRNP and the possible effects of climate change on the distribution patterns is needed.

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