



Biodiversity and dynamics of plant groups of Chebket El Melhassa region (Algeria)

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This article examines phytocological aspects of plant groups in the Chebket El Melhassa region (Tiaret-Ouest Algérie) by several types of analysis: biological, biogeographic and statistical. From the plant analysis, a list of 103 taxa distributed in 36 families was compiled, biologically characterized by a dominance of therophytes (45.6%) with species of the Mediterranean biogeographic type 20 species (19.8%) assuming particular importance. The ordination of the plant community was performed in the search for the optimum solution based on correlation with environmental factors, estimated using the phytindication approach. The results reveal that the plants represented in the community, mostly prefer strongly lit places. Phytindication shows a warm sub Mediterranean climate. Continentality corresponds to the sub-oceanic climate. The moisture regime ranges from strongly dry to dry soil. The plant community is formed on moderately acid soils. Plants are able to grow on both strongly acidic and neutral soils. The soil is very poor or poor in nitrogen. A four dimension variant of multidimensional scaling procedure was selected as the most appropriate decision. Dimensions selected after nonmetric multidimensional scaling were interpreted by computing weighted average scores of ecological factors for ordination configuration. Four of the plant species clusters were found to be the optimal solution on the basis of the Calinsky-Harabasz criteria. The clusters can be viewed as a functional group. Functional group A is quite diverse and represented by 42 species. This functional group is closest to the community optimum because in all four space dimensions the corresponding cluster is near the origin, which corresponds to the most typical ecological conditions. Species that constitute the group B prefer minimum values of dimension 2. This indicates a preference for illuminated sites with high temperature regime and low soil humidity. This group includes 32 species. A feature of group C is that it is located in the area of maximum values for dimension 2. Thus, this functional group is opposite to functional group B. This indicates a preference of species included in the functional group C for wetter soils. Functional group C comprises 21 species. Functional group D differs considerably from all others in its ecological characteristics. The difference is in the preference for minimum values for measurement 1. This suggests that more acid soils are optimal for a given functional group. Functional group E comprises 8 species.

Key words: Phytocology, vegetation dynamics, F.A.C, Chebket El Melhassa, Tiaret

Introduction

In the global context of preserving biodiversity, the study of the flora and vegetation of the Mediterranean basin is of great interest because of its richness linked to the heterogeneity of historical, paleogeographic, paleoclimatic, ecological and geological factors and the secular impact of anthropogenic pressure (Quézel et al., 1980).

Arid and semi-arid regions in North Africa are currently experiencing degradation of natural resources. Vegetation formations (forests, pre-forests, matorrals and steppes) are regressing under climatic-anthropic impact. This dual action leads to physiognomic and landscape changes, which have led to major changes in bio-resources (Hasnaoui & Bouazza, 2015). For example, in Algeria, the forest heritage, like that of the other Mediterranean zones, has experienced a continuous regression due to a combined action of man (deforestation, overgrazing) and

climate (decaying summer, irregular rains, violent showers). This evolution has led to the substitution of the original mesophytic vegetation, by a xerophytic vegetation to varying degrees (Benabadj & Bouazza, 2001).

Phytocenoses consists of species of which the ecological amplitude overlap. Each species has an indicator value, but an indication cannot be made on the basis of the one species. The composition of species can be used to quantify the properties of the environment, which cannot easily be measured directly, unlike, for example, pollution (Austin, 2013). Phytindicator scales can be considered as markers of environmental properties. Correctly recorded vegetation plots are less influenced by spatial and temporal variability than single field measurements of environmental factors (Horsák et al., 2007). The composition reflects the distribution of the resulting group of species that make up a phytocoenosis.

Ellenberg indicator values represent the realized ecological optimum plant species in the form of ordinal digits. Weighted indicator

values for plants of the group are used as a surrogate assessment of the values of the ecological factors (Diekmann, 2003). The disadvantages of the method of average weighted indicator values include the fact that this method does not take into account the point the absence of species. So it can reach the ironic conclusion that telegraph poles demonstrate optimum pH (Ashby, 1936). From a purely mathematical standpoint, the method of average values weighted indicator values is not acceptable, as indicating the value measured in the ordinary scales. However, it is postulated that the ordinal nature of the Ellenberg indicator values is much less important in comparison with the response curve types, which should be symmetrical (ter Braak & Gremmen, 1987). In this case, mean and median are largely indistinguishable (Diekmann, 2003). So there are no practically significant arguments that could deny the use of the average values for the purposes of phytosociation (Seidling & Fischer, 2008). Furthermore it was shown that curve distributions that are close to Gauss symmetrical average values give a reliable phytosociation score (ter Braak & Looman, 1986).

Previous studies (Cherifi et al., 2011; Stambouli-Meziane & Bouazza, 2012; Benabadi et al., 2014), on the flora and its diversity in the west of Algeria, reveal the degree of disturbance of these ecosystems, where anthropozoic factors play a major role in the organization of vegetation structures. Given the magnitude of these phenomena, which is constantly increasing, phytocological studies are essential

criteria for any conservation strategy. In this respect, our vegetational and floristic study of the Chebket El Melhassa region (Tiaret, West Algeria) is of great interest.

The purpose of this article is to perform the ordination of the plant community in the search for the optimum solution based on correlation with environmental factors, estimated using the phytosociation approach.

Materials and methods

Chebket El Melhassa belongs to the commune of Faidja, it is located about 90 km south of the capital of the wilaya of Tiaret (Fig. 1). It is bordered to the North by the municipalities of Nadorah and Sidi Abdelghanie, to the West by the municipality of Naïma, to the East by the municipality of Zmalet Emir Abdelkader and to the South by the Wilayas of Djelfa and Laghouat. The climate is Mediterranean with an average rainfall of 269.47 mm/year, the minimum average of the coldest month (m) is 3.01 °C and the maximum average of the warmest month (M) is 38.08 °C. The dry period is more or less long, extending from March to November (Benkhettou et al., 2015).

The sigmatist Braun-Blanquet (Braun-Blanquet, 1951) phytosociological method (floristic surveys) was used. In the Mediterranean region, the minimum area is between 100 and 400 m² for forestry groups, and between 50 and 100 m² for matorral (Benabid, 1984).

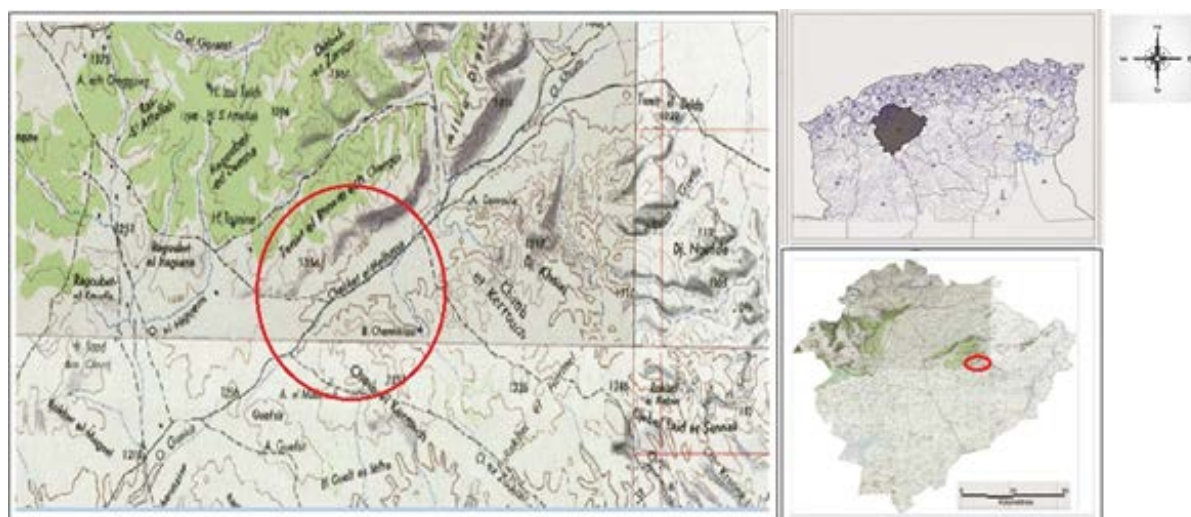


Fig. 1. Geographic location of Chebket El Melhassa

In our case, we selected an area of 100 m². 30 surveys were carried out during a favourable floristic season (March to June) of 2015, each vegetation survey consisted of an exhaustive inventory of all the plant species encountered according to strata (tree, shrub and herbaceous) and each species was accompanied by two indices: abundance-dominance and sociability. The identification of taxa was made from the new flora of Algeria (Quézel & Santa, 1962). The identification of species took a long time because of lack of experts in botany. The perturbation index (PI) was calculated from the formula (Loisel & Gamila, 1993):

$$PI = \frac{\text{numbers of chamephytes} + \text{number of therophytes}}{\text{total number of species}} * 100$$

Ellenberg indicator values (1974) include: L-scale of illumination / shading (9 classes, Light Regime), T-scale of thermo climate (9 classes, temperatures), K-scale of climate continentality (9 classes, continentality of climate), F-scale of soil moisture (9 classes, humidity), R-scale of soil acidity (9 classes, acidity), and N-scale of soil nitrogen (9 classes, nutrients availability). Estimation of values of environmental factors was carried out using the method of average weighted values of indicator scales taking into account the protective coating of plants. Ellenberg indicator values were modified to reflect local differences in species ecological properties, e.g. in Switzerland, Poland, British Isles and Italy (Landolt, 1977; Hill et al., 1999; Zarzycki, 1984; Pignatti et al., 2005). Ellenberg-Pignatti values from Italy were shown to be useful for phytosociation purposes in the Mediterranean ecosystems (Vitasović Kosić et al., 2017). For the plant species which are not included in the

Pignatti list, the indicator values were calculated as the weighted average of ecological factors in the sites of detection of these plants.

To decrease the dimension of the plant table, nonmetric multidimensional scaling was applied (Minchin, 1987). As measures of distance between sample points in the community space, the following metrics have been used: Euclidean, Manhattan, Gower, Bray-Curtis, Kulczynski, Morisita, Horn-Morisita, Cao, Jaccard, Mountford, Raup-Crick, Canberra, Chao (Oksanen, 2017). The selection of appropriate distance metric and variants of primary data preliminary transformation was made on the basis of Spearman rank correlations coefficients between dissimilarity indices and gradient separation (Legendre & Gallagher, 2001). Multidimensional scaling was conducted using library ade4 (Dray et al., 2007) in the environment R (R Core Team, 2016).

Results and discussion

The inventoried flora has about 103 species, belonging to 36 families and 87 genera (Table 1). The Gymnosperms represent only 3.0%, whereas the Angiosperms dominate widely with 97.0% with (72.5% for the Eudicots and 24.5% for the Monocots). The distribution of families is heterogeneous. We noticed the dominance of the Asteraceae family with (22.3%), followed by Poaceae (12.6%), Brassicaceae, Caryophyllaceae and Lamiaceae in third position with the same percentage (5.8%), followed by Apiaceae (4.9%) and Cistaceae (3.9%) (Fig. 2). Among the other families, 22 are mono-generic (0.9%)

such as Asphodelaceae, Convolvulaceae and Plantaginaceae and one (1) other family is mono-specific, the Lauraceae family.

Table 1

Flora taxonomy structure and Ellenberg indicator values

No	Family	Taxa	FG	Ellenberg indicator values						
				L	T	K	F	R	N	Source
1	Alliaceae	<i>Allium subhirsutum</i> L.	A	8	9	4	2	4	2	Pignatti
2	Anacardiaceae	<i>Pistacia atlantica</i> Desf.	B	9	8	4	3	5	3	Estimated
3		<i>P. lentiscus</i> L.	A	1	1	5	2	5	2	Pignatti
4		<i>P. terebinthus</i> L.	B	9	8	5	2	7	2	Pignatti
5	Apiaceae	<i>Ammi majus</i> L.	A	11	9	5	4	5	2	Pignatti
6		<i>Bupleurum rotundifolium</i> L.	A	8	7	5	3	9	4	Pignatti
7		<i>Daucus carota</i> (Desf.) Batt.	B	8	6	5	4	5	4	Pignatti
8		<i>Eryngium campestre</i> L.	B	9	7	5	3	8	3	Pignatti
9		<i>Ferula communis</i> L.	B	9	8	5	3	5	2	Pignatti
10	Asparagaceae	<i>Asparagus officinalis</i> L.	C	8	8	5	5	5	5	Pignatti
11	Asphodelaceae	<i>Asphodelus microcarpus</i> Salzm et Viv.	A	1	9	4	2	3	5	Pignatti
12	Asteraceae	<i>Anacyclus cyrtolipidioides</i> Pomel	D	10	8	5	3	6	3	Estimated
13		<i>Artemisia herba-alba</i> Asso	A	9	8	4	3	5	3	Estimated
14		<i>Atractylis aristata</i> Batt.	C	9	8	4	3	5	3	Estimated
15		<i>A. cancellata</i> L.	C	11	8	5	2	6	2	Pignatti
16		<i>A. humilis</i> L.	B	10	8	4	3	5	3	Estimated
17		<i>A. cardioides</i> (Forssk.) C. Chr.	A	9	8	4	3	5	3	Estimated
18		<i>Bellis sylvestris</i> L.	A	5	8	4	3	3	3	Pignatti
19		<i>Calendula arvensis</i> L.	A	7	8	5	3	8	5	Pignatti
20		<i>Carduus nutans</i> L.	D	8	8	5	3	8	6	Pignatti
21		<i>C. pycnocephalus</i> L.	A	7	8	4	3	5	3	Pignatti
22		<i>Carlina gummifera</i> (L.) Less.	B	11	11	5	1	7	1	Pignatti
23		<i>Catananche caerulea</i> L.	C	11	8	3	4	6	2	Pignatti
24		<i>Centaurea pullata</i> L.	A	9	8	4	3	5	3	Estimated
25		<i>Glebionis segetum</i> (L.) Fourr.	B	7	6	4	5	5	5	Pignatti
26		<i>Echinops spinosissimus</i> Turra	B	11	12	3	2	5	2	Pignatti
27		<i>Hypochaeris radicata</i> L.	D	9	8	4	2	6	1	Pignatti
28		<i>Launaea arborescens</i> (Batt.) M.	B	10	8	4	3	6	3	Estimated
29		<i>Leucanthemum paludosum</i> (Poir.) Bonnet & Barratte	B	9	8	4	3	5	3	Estimated
30		<i>Matricaria chamomilla</i> L.	B	7	5	5	6	5	5	Pignatti
31		<i>Scolymus hispanicus</i> L.	B	11	8	5	3	5	2	Pignatti
32		<i>Podospermum laciniatum</i> (L.) DC.	A	7	8	6	3	8	3	Pignatti
33		<i>Taraxacum obovatum</i> (Willd.) DC.	A	7	6	4	4	6	6	Pignatti
34		<i>Artemisia campestris</i> L.	A	9	6	5	3	5	2	Pignatti
35		<i>Borago officinalis</i> L.	A	7	8	5	3	5	5	Pignatti
36	Boraginaceae	<i>Echium humile</i> Desf.	A	10	8	4	3	5	3	Estimated
37		<i>Lappula redowskii</i> Hornem (Greene)	C	9	8	4	3	5	3	Estimated
38	Brassicaceae	<i>Alyssum granatense</i> Boiss. & Reut.	D	9	9	4	2	7	1	Pignatti
39		<i>Lepidium draba</i> L.	A	8	7	7	3	8	4	Pignatti
40		<i>Matthiola lunata</i> DC.	C	9	8	4	3	5	3	Estimated
41		<i>M. parviflora</i> (Schousb.) R.Br.	B	10	8	4	3	5	3	Estimated
42		<i>Sisymbrium irio</i> L.	B	8	8	5	3	7	5	Pignatti
43		<i>Sinapis arvensis</i> L.	C	7	5	4	3	8	6	Pignatti
44		<i>Paronychia arabica</i> (L.) DC.	A	9	8	4	3	5	3	Estimated
45	Caryophyllaceae	<i>Paronychia argentea</i> Lam.	A	11	8	4	2	2	1	Pignatti
46		<i>Silene gallica</i> L.	B	8	9	5	3	2	1	Pignatti
47		<i>Sclerocephalus arabicus</i> Boiss.	B	9	8	4	3	5	3	Estimated
48		<i>Silene vulgaris</i> (Moench) Garcke	D	8	8	5	4	7	2	Pignatti
49		<i>Telephium sphaerospermum</i> Boiss.	B	9	8	4	3	5	3	Estimated
50		<i>Chenopodium murale</i> L.	B	8	7	5	4	5	9	Pignatti
51		<i>Haloxylon scoparium</i> Pomel	B	9	8	4	3	5	3	Estimated
52	Cistaceae	<i>Cistus albidus</i> L.	B	11	9	4	2	3	2	Pignatti
53		<i>C. monspeliensis</i> L.	B	1	9	4	2	2	2	Pignatti
54		<i>Helianthemum hirtum</i> (L.) Miller	B	11	11	3	1	2	1	Pignatti
55		<i>H. helianthemoides</i> (Desf) Grosser.	A	9	8	4	3	5	3	Estimated

No	Family	Taxa	FG	Ellenberg indicator values						
				L	T	K	F	R	N	Source
56	Convolvulaceae	<i>Convolvulus althaeoides</i> L.	D	8	9	4	3	5	2	Pignatti
57	Crassulaceae	<i>Sedum album</i> L.	B	11	8	5	2	5	1	Pignatti
58	Cupressaceae	<i>Juniperus phoenicea</i> L.	A	11	8	5	2	4	2	Pignatti
59		<i>Tetraclinis articulata</i> (Vahl.) Masters	C	11	12	5	3	8	2	Pignatti
60	Dipsacaceae	<i>Juniperus oxycedrus</i> L.	A	8	8	5	3	5	2	Pignatti
61		<i>Lomelosia stellata</i> L.	B	7	7	4	4	5	2	Pignatti
62	Fabaceae	<i>Astragalus cruciatus</i> Unk.	A	9	8	4	3	5	3	Estimated
63		<i>Calicotome spinosa</i> (L.) Link	A	12	1	4	2	5	2	Pignatti
64	Fagaceae	<i>Hippocrepis scabra</i> DC.	B	9	8	5	2	7	2	Pignatti
65		<i>Quercus ilex</i> L.	A	2	9	4	3	5	3	Pignatti
66	Géraniaceae	<i>Erodium glaucophyllum</i> L.Her.	A	11	12	6	2	7	3	Pignatti
67		<i>Geranium rotundifolium</i> L.	D	7	8	5	3	6	3	Pignatti
68	Hyacinthaceae	<i>Muscari comosum</i> (L.) Mill.	A	9	8	5	3	5	2	Pignatti
69		<i>Urginea maritima</i> L.	C	11	1	3	1	4	2	Pignatti
70	Lamiaceae	<i>Marrubium vulgare</i> L.	B	9	8	5	3	8	8	Pignatti
71		<i>Menha rotundifolia</i> L.	C	7	5	5	8	8	8	Pignatti
72		<i>Rosmarinus officinalis</i> L.	A	1	8	4	2	6	1	Pignatti
73		<i>Salvia officinalis</i> L.	C	11	6	6	2	7	1	Pignatti
74		<i>S. verbenaca</i> (L.) Briq.	C	8	8	4	3	5	7	Pignatti
75	Lauraceae	<i>Thymus ciliatus</i> Desf.	C	9	8	4	3	6	3	Estimated
76		<i>Laurus nobilis</i> L.	B	2	7	4	8	4	6	Pignatti
77	Malvaceae	<i>Malva sylvestris</i> L.	A	8	6	4	4	5	8	Pignatti
78	Oleaceae	<i>Phillyrea angustifolia</i> L.	C	11	1	4	1	5	2	Pignatti
79	Orobanchaceae	<i>Orobancha crenata</i> Forsk.	A	8	5	6	3	5	4	Pignatti
80	Palmaceae	<i>Chamaerops humilis</i> L.	A	11	1	3	1	4	1	Pignatti
81	Papaveraceae	<i>Papaver rhoeas</i> L.	A	6	6	5	5	7	3	Pignatti
82	Plantaginaceae	<i>Globularia alypum</i> L.	C	11	8	4	2	2	1	Pignatti
83		<i>Aegilops geniculata</i> Roth	A	11	1	4	5	5	4	Pignatti
84		<i>Ampeodesmos mauritanicus</i> (Poir.) T. Durand & Schinz	A	8	11	3	2	5	2	Pignatti
85		<i>Avena sativa</i> L.	B	8	7	6	5	6	6	Pignatti
86		<i>A. sterilis</i> L.	C	8	9	5	3	6	4	Pignatti
87		<i>Aristida pungens</i> Desf.	A	10	8	5	3	5	3	Estimated
88		<i>Briza minor</i> L.	B	8	9	5	2	4	1	Pignatti
89	Poaceae	<i>Bromus rubens</i> L.	C	8	11	5	2	5	2	Pignatti
90		<i>Ctenopsis pectinella</i> (Del.) De Not.	C	9	8	4	3	5	3	Estimated
91		<i>Hordeum murinum</i> L.	A	8	8	4	5	5	3	Pignatti
92		<i>Lolium multiflorum</i> Lam.	A	7	7	5	4	5	6	Pignatti
93		<i>L. rigidum</i> Gaud.	C	8	8	5	3	4	2	Pignatti
94		<i>Lygeum spartum</i> L.	B	12	11	4	1	7	1	Pignatti
95		<i>Stipa tenacissima</i> L.	A	9	8	4	3	5	3	Estimated
96		<i>Anagallis arvensis</i> L.	A	6	6	5	5	5	6	Pignatti
97	Resedaceae	<i>Reseda alba</i> L.	A	11	8	4	3	7	1	Pignatti
98	Rhamnaceae	<i>Ziziphus lotus</i> (L.) Lam.	D	11	12	5	1	7	1	Pignatti
99	Tamaricaceae	<i>Tamarix gallica</i> L.	C	11	7	4	6	5	3	Pignatti
100	Thymelaeaceae	<i>Thymelaea hirsuta</i> (L.) Endl.	A	11	8	5	2	5	3	Pignatti
101	Urticaceae	<i>Urtica dioica</i> L.	A	9	8	4	6	5	8	Estimated
102	Valerianaceae	<i>Valeriana tuberosa</i> L.	C	11	4	5	5	7	3	Pignatti
103	Zygophyllaceae	<i>Peganum harmala</i> L.	B	12	12	6	1	7	7	Pignatti

Notes: FG – functional groups; L – light regime; T – temperatures; K – continentality of climate; F – humidity; R – acidity; N – nutrients availability.

Indeed, the importance of the families that occupy the first places is explained by its adaptation to the various actions exerted on the environment. From a morphological point of view, the plant formations are marked by the heterogeneity between woody and herbaceous plants and between perennials and annuals.

The herbaceous annuals (HA) dominate with a percentage of 45.6%, followed by perennial herbs (HV) 39.8% and finally, perennial woody (LV) with 14.6%. The production of the raw biological spectra is based on the enumeration of the taxa by biological type and carried out on the totality of the species of each group. The determination of the

biological types was carried out according to the method of Raunkiaer (1905). The plant structure of the study area is schematically represented as follows: Th > Ch > He > Ph > Ge. Table 2 shows the results of the floristic composition according to the biological characterization.

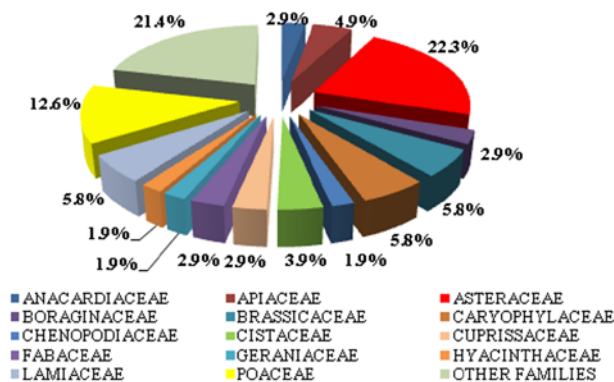


Fig. 2. Composition of the flora by family (% from the total species number)

Table 2
Percentage of Raunkiaer plant life-forms

Biological Types	Ph	Ch	He	Ge	Th	Total	Biological Spectrum
Number of species	10	19	18	9	47	103	Th > Ch > He >
Percentage (%)	9.7	18.4	17.5	8.7	45.6	100	Ph > Ge

Notes: Ph – phanerophytes; Ch – chamaephytes; He – hemicryptophytes; Ge – geophytes; Th – therophytes; source: authors personal data

The results show that Therophytes (TH) have the highest level with 45.6%, the most abundant species being *Bellis sylvestris*, *Calendula arvensis*, *Chrysanthemum segetum*, *Sinapis arvensis*, *Malva sylvestris*, *Aegilops geniculata*. Several authors agree that this therophytisation is linked to the harsh climate and to anthropogenic actions that are increasingly degrading the conditions for the colonisation of new species. Daget (1980) thinks that, in any case, the rate of therophytes is linked, whatever the scale of the analysis and the level of perception adopted, to the opening of the vegetation and to the overall humidity of the environment. The chamaephytes (Ch) represented mainly by *Chamaerops humilis*, *Calycotome spinosa*, *Ampelodes mamauritanicum*, *Cistus monspeliensis*, have a percentage of 18.4%. These species shape the physiognomy of these ecosystems by adapting them to the xeric conditions of the environment. They have strong capacity to withstand the burden of animal overload and other forms of anthropogenic stress, mainly fires and cutting. The hemicryptophytes (He) occupy an important place. They occupy the third position in the plant formations studied. 18 species make up this group, i.e. 17.5% of all the species listed. Among these species are: *Eryngium campestre*, *Atractylis aristata*, *Carduus pycnocephalus*, *Echinops spinosus* and *Astragalus cruciatus*. Phanerophytes (Ph) mainly represented by hardwoods such as *Quercus ilex*, *Pistacia atlantica*, *P. lentiscus*, *Phillyrea angustifolia* and conifers such as *Tetraclinis articulata*, *Juniperus oxycedrus* and *J. phoenicea* make up 9.7% of the species listed. Geophytes (Ge) are also present with 9 species (8.7%). The aridity of the environment, coupled with the strong pressure exerted by man and his herds, causing important phenomena of water stress and adaptation (chemo and morphotactic) in plants, has led to the progressive invasion by plant groups dominated mainly by toxic species such as *Asphodelus microcarpus*, *Urginea maritima*, *Urtica dioica* or thorny plants such as *Asparagus officinalis*. The calculated perturbation index (PI) is of the order of 64.1%. PI indicates the invasion of annual short-lived herbaceous plants; the latter express a strategy of adaptation to unfavourable conditions and a form of resistance to climatic rigours. On the other hand, perennial trees are more demanding in water and trophic needs.

The analysis of the species recorded by biogeographic types showed the predominance of Mediterranean biogeographic species with 20 species (19.8%), West-Mediterranean and Eurasian types are represented by 7 species (6.9%), followed by the North African endemics

4 species (4.1%). The Palaeo-Tempere, European, Circum-Mediterranean and Cosmopolite elements occupy 5th position with three species (3.2%). The other types represent a low participation: two species (2%) as Circumboreal, one species (1.3%) such as Saharan Mediterranean. Despite this low participation, these elements contribute to the phyto-geographical diversity of the studied region.

Phytoecological analysis makes it possible to specify the effect of ecological factors on the dispersal, development, abundance and arrangement of plant species. Indeed, the distribution and the structure of the plant groups maintained close relations with the ecological environment. This part of the work presents the global approach which focuses mainly on statistical treatment of floristic survey tables in order to understand the dynamics of plant groups and to show ecological gradients.

Phytoindication provided an opportunity to establish the statistical characteristics of the variation of environmental factors within the study area (Table 3).

Table 3
Descriptive statistics of the phytoindicator assessed ecological factors

Ecological factor	Median	Minimum	Maximum	Lower	Upper
Light regime	8.84	8.27	9.19	8.67	8.94
Temperatures	8.09	7.73	8.34	7.91	8.17
Continentality of climate	4.48	4.33	4.60	4.44	4.50
Humidity	2.86	2.67	3.02	2.72	2.90
Acidity	5.44	5.20	5.77	5.40	5.50
Nutrients Availability	2.89	2.70	3.14	2.85	3.03

The results reveal that the plants represented in the community mostly prefer strongly lit places. Phytoindication shows a warm sub Mediterranean climate. Continentality corresponds to the sub-oceanic climate. It is found that the moisture regime is in the range from strongly dry to dry soil. The plant community is formed on moderately acid soils. Plants are able to grow on both strongly acidic and neutral soils. The soil is very poor or poor in nitrogen.

Environmental factors can be used to determine the optimal solution for the ordination of plant communities using the method of multidimensional scaling. The methodological approach is that of all the possible ecological distances within data matrix plants/sites and transformation methods, the one that gives the highest correlation with environmental factors should be selected. Spearman rank correlations coefficients between dissimilarity indices and gradient separation with different data transformation methods have revealed that usage of divided by margin total data and Euclidean distance is the most appropriate approach to reflect the relationship between soil mechanical impedance and ecological factors (Table 4). In further calculations the experimental data will be used in the above-mentioned transformed way.

Stress is a goodness-of-fit statistic in multidimensional scaling based on the differences between the actual distances and their predicted values. One of the goals of multidimension scaling analysis is to keep the number of dimensions as small as possible. The usual technique is to solve the multidimensional scaling problem for a number of dimension values and adopt the smallest number of dimensions that achieves a reasonably small value of stress. An appropriate number of dimensions was chosen by performing ordinations of progressively higher numbers of dimensions. A stress versus number of dimensions screen diagram was then plotted, on which one can identify the point beyond which additional dimensions do not substantially lower the stress value (Fig. 6). A four dimension variant of multidimensional scaling procedure was selected as the most appropriate decision.

Four dimensions selected after nonmetric multidimensional scaling (NMDS) were interpreted by computing weighted average scores of ecological factors for ordination configuration (Table 5).

It has been established that such predictors as light regime, temperatures, humidity, and acidity are statistically significant. They are able to explain from 42% to 48% of the dimension variation. The dimension MDS1 may be interpreted as the measure of the soil acidity which is controversially correlated with light regime. The dimension MDS2 is most sensitive to controversial correlation of the humidity on the one hand and temperature on the other. The dimension MDS3 is most sensitive to the soil acidity. The dimension MDS4 is most sensitive to the soil humidity.

Table 4

Spearman rank correlation coefficients between dissimilarity indices and gradient separation with different data transformation methods

Distance	Data transformation methods										
	1	2	3	4	5	6	7	8	9	10	11
Euclidean	-0.32	0.33	0.34	0.46	0.11	0.10	0.43	0.17	0.44	0.39	0.31
Manhattan	-0.28	0.33	0.32	0.40	0.13	0.15	0.35	0.16	0.39	0.34	0.14
Gower	-0.16	0.28	0.25	0.25	0.16	0.16	0.05	0.16	0.28	0.25	0.14
Bray-Curtis	-0.40	0.39	0.40	0.40	0.28	0.31	0.39	0.31	0.39	0.36	0.14
Kulczynski	-0.42	0.40	0.41	0.40	0.30	0.33	0.40	0.32	0.39	0.37	0.14
Morisita	-0.43	NA	0.10	-0.10	-0.16	-0.02	-0.34	-0.12	-0.27	-0.12	-0.01
Horn-Morisita	-0.43	0.43	0.44	0.43	0.27	0.29	0.43	0.30	0.44	0.40	0.27
Cao	-0.33	0.22	0.25	NA	0.25	0.33	0.44	0.32	0.45	0.36	NA
Jaccard	-0.40	0.39	0.40	0.40	0.28	0.31	0.39	0.31	0.39	0.36	0.14
Mountford	-0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.39	0.29	0.29	0.29
Raup-Crick	-0.08	-0.08	-0.08	-0.08	-0.08	-0.08	-0.08	-0.09	-0.08	-0.08	-0.08
Canberra	-0.30	0.28	0.28	0.26	0.30	0.30	0.21	0.38	0.27	0.26	0.14
Chao	-0.04	0.04	0.04	0.16	NA	0.11	0.16	NA	0.19	0.08	0.07
Mahalanobis	-0.09	0.11	0.11	0.19	0.14	0.09	0.09	0.13	0.16	0.15	0.15

Notes: bold marked the highest correlation coefficient; NA – not available; 1 – untransformed data; 2 – log-transformed data; 3 – square-root transformed data; 4 – divided by margin total; 5 – divided by margin maximum; 6 – divided by margin maximum and multiplied by the number of non-zero items, so that the average of non-zero entries is one; 7 – normalized (margin sum of squares equal to one); 8 – standardized values into range 0–1; 9 – Hellinger transformation; 10 – χ^2 -transformation; 11 – Wisconsin transformation.

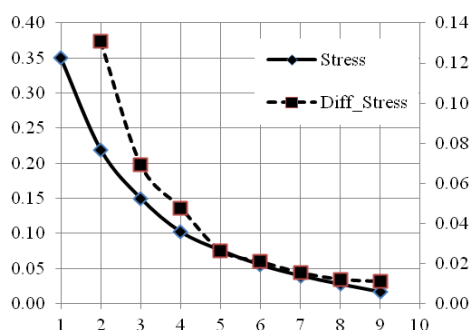


Fig. 6. Stress versus number of dimensions screen diagram: arrow shows optimal number of dimensions: abscissa – the number of dimensions; ordinate – stress (left axis) or differential stress (right axis)

Table 5

Fitting environmental factors onto an ordination

Ecological factors	MDS1	MDS2	MDS3	MDS4	r^2	Pr(>r)	Significance codes
Light Regime	0.58	-0.73	-0.15	0.33	0.48	0.00	***
Temperatures	-0.26	-0.84	0.37	-0.30	0.48	0.00	**
Continental of Climate	-0.77	-0.26	0.25	-0.53	0.07	0.79	n.s.
Humidity	0.12	0.74	0.13	-0.65	0.42	0.01	**
Acidity	-0.70	-0.38	0.53	-0.30	0.44	0.01	**
Nutrients Availability	0.60	-0.53	0.19	0.57	0.21	0.21	n.s.

Notes: *** – < 0.001 ; ** – < 0.01 ; * – < 0.05 ; n.s. – not significant.

Fitting environmental factors onto an ordination by means of linear models is quite far from the real character of the relation between ecological factors and community structure. Smoothing surface for some ecological factors within the ordination diagram shows a complicated and nonlinear response of the vegetation due to ecological factors impact (Fig. 7). As shown in the figures, the linear coefficients indicate only a priority trend in the changes in the plant community structure.

Multidimensional scaling allows us to estimate how placement of sampling points, and plant species in the same space. Measured values for the plant can be used for cluster analysis of the plant community. An important aspect of cluster analysis is to identify the optimal number of clusters. This problem was solved by means of Calinsky-Harabasz criteria (Fig. 8). Four of the clusters were found to be the optimal solution. Cluster solution can be represented as a dendrogram (Fig. 9). Also ellipsoids can designate the configuration of species that belong to one cluster, in the dimension space (Fig. 10).

The clusters can be viewed as a functional group. The information obtained allows us to interpret the functional groups in terms of their

environmental characteristics. Functional group A is a closest to the community optimum because in all four space dimensions the corresponding cluster is near the origin, which corresponds to the most typical ecological conditions. This functional group is a quite diverse. The functional group A comprises 42 species. Species that constitute the group B prefer minimum values of dimension 2. This indicates a preference for illuminated sites with high temperature regime and low soil humidity. Thus, the functional group B is species of open dry spaces. This group includes 32 species. The main feature of group C is that it is located in the area of maximum values for dimension 2. Thus, this functional group is opposite to functional group B. This indicates the preference of species included in the functional group C for wetter soils. Functional group C comprises 21 species. Functional group D most considerably differs from all others in its ecological characteristics. The difference is in the preference for minimum values for measurement 1. This suggests that more acidic soils are optimal for a given functional group. Functional group E comprises 8 species.

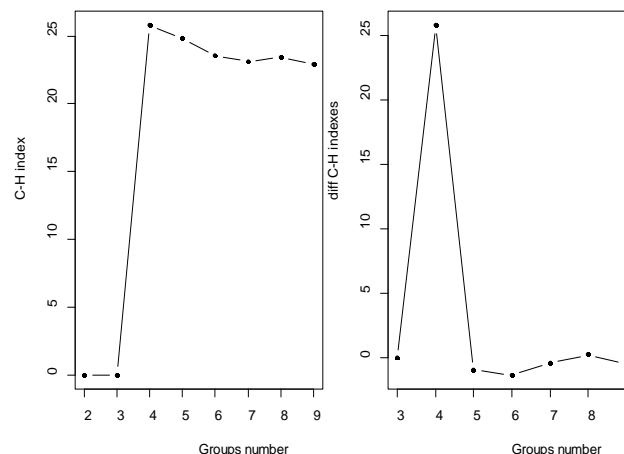


Fig. 8. Usage of the Calinsky-Harabasz criteria (C-H index) to find the best vegetation community partition

Discussion

Structures of plant communities can be identified through ordination (Pélissier et al., 2003). Among the many approaches to community ordination, multidimensional scaling can be considered as one of the most appropriate tools (Zhukov, 2015). One of its advantages is that it uses a great diversity of distance measures and methods of data pre-transformation (Allen et al., 1984). However, this feature creates difficulties associated with the optimal choice solutions. This problem can

be solved by maximizing the correlation matrix of measures distances between species in community and ecological properties of the environ-

ment. This approach allowed us to establish that for the studied community Euclidean distance is the best measure of distance.

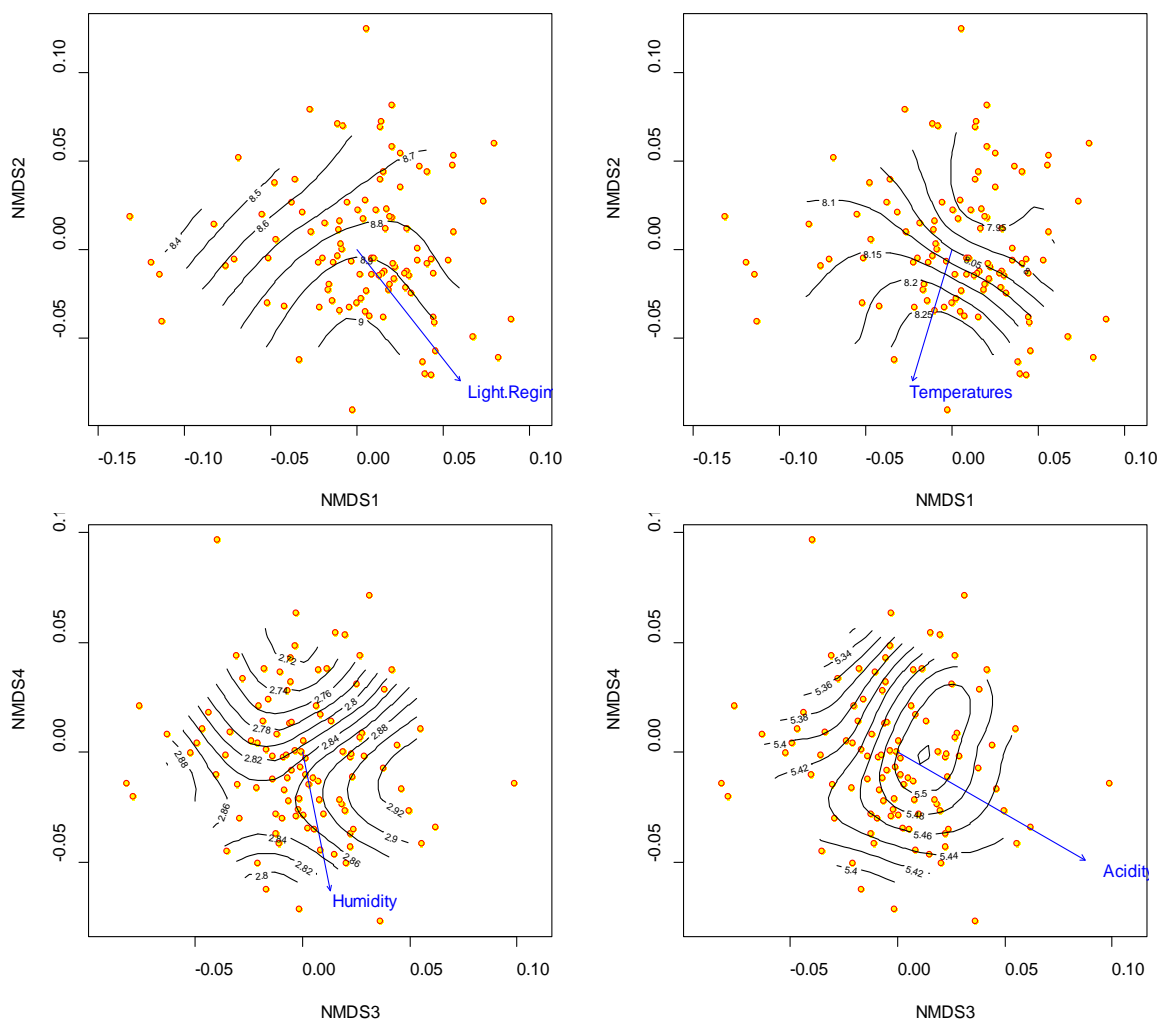


Fig. 7. Smoothing surface for some ecological factors within ordination diagram

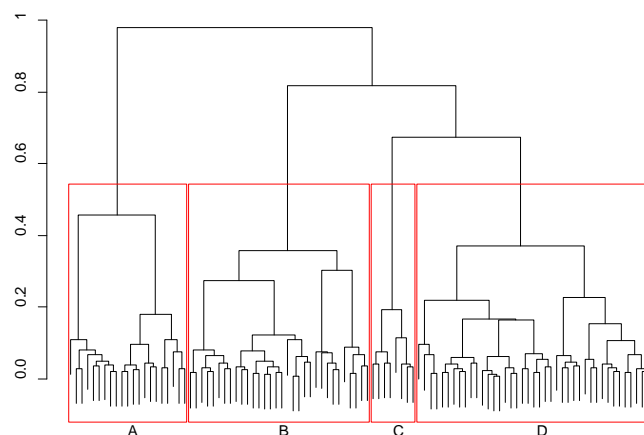


Fig. 9. Vegetation community cluster analysis (Ward method, Euclidean distance). A, B, C, D – clusters (functional groups)

The phytoindication method was applied as a source of information on ecological factors. This approach has independent significance. We have obtained a quantitative assessment of the ecological factors that may affect the structure of the community. Vegetation classification made it possible to establish the existence of four functional groups.

Functional group A is a quite diverse and represented by 42 species. In this group we notice the installation of a tree formation consisting mainly of *Quercus ilex*, *Juniperus oxycedrus*, *J. phoenicea*, *Pistacia lentiscus* and *Tetraclinis articulata*. This formation represents the limit of the

wooded vegetation of the Djebel Nador massif. Deviation from the conditions favourable to the functional group leads to the impossibility of the existence of forest vegetation (Brygadyrenko, 2015; 2016). We observed the colonisation of certain species that mark anthropization (*Chamaerops humilis*). It should be noted that the diversity of this group is also due to the presence of herbaceous plants such as *Stipa tenacissima*, *Artemisia herba-alba*, *Hordeum murinum*. Therophyte species are represented by *Taraxacum obovatum* and *Bellis sylvestris*. We also noted the presence of species that dominate by their biomass such as *Stipa tenacissima*.

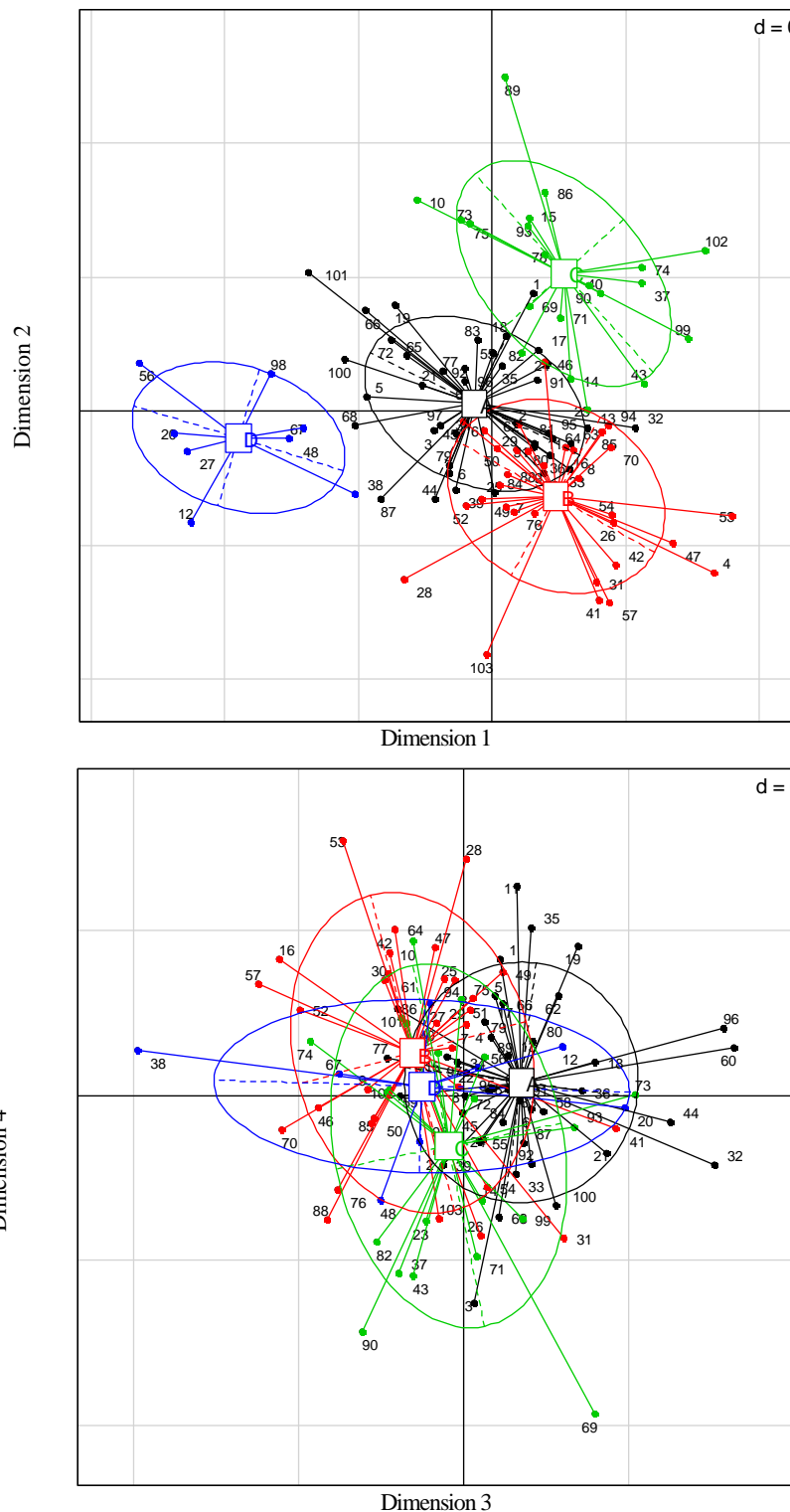


Fig. 10. Species distribution and cluster configuration in multidimensional space: 1 – *Allium subhirsutum*; 2 – *Pistacia atlantica*; 3 – *Pistacia lentiscus*; 4 – *Pistacia terebinthus*; 5 – *Ammi majus*; 6 – *Bupleurum rotundifolium*; 7 – *Daucus carota*; 8 – *Eryngium campestre*; 9 – *Ferula communis*; 10 – *Asparagus officinalis*; 11 – *Asphodelus microcarpus*; 12 – *Anacyclus cyrtolepidioides*; 13 – *Artemisia herba-alba*; 14 – *Atractylis aristata*; 15 – *Atractylis cancellata*; 16 – *Atractylis humilis*; 17 – *Atractylis carduus*; 18 – *Bellis sylvestris*; 19 – *Calendula arvensis*; 20 – *Carduus nutans*; 21 – *Carduus pycnocephalus*; 22 – *Carlina gummifera*; 23 – *Catananche caerulea*; 24 – *Centaurea pullata*; 25 – *Glebionis segetum*; 26 – *Echinops spinosus*; 27 – *Hypochaeris radicata*; 28 – *Launaea arborescens*; 29 – *Leucanthemum paludosum*; 30 – *Matricaria chamomilla*; 31 – *Scolymus hispanicus*; 32 – *Podospermum laciniatum*; 33 – *Taraxacum obovatum*; 34 – *Artemisia campestris*; 35 – *Borago officinalis*; 36 – *Echium pycnanthum*; 37 – *Lappula redowskii*; 38 – *Alyssum granatense*; 39 – *Lepidium draba*; 40 – *Matthiola lunata*; 41 – *Matthiola parviflora*; 42 – *Sisymbrium irio*; 43 – *Sinapis arvensis*; 44 – *Paronychia arabica*; 45 – *Paronychia argentea*; 46 – *Silene gallica*; 47 – *Sclerocephalus arabicus*; 48 – *Silene vulgaris*; 49 – *Telephium sphaerospermum*; 50 – *Chenopodium murale*; 51 – *Haloxylon scoparium*; 52 – *Cistus albidus*; 53 – *Cistus monspeliensis*; 54 – *Helianthemum hirtum*; 55 – *Helianthemum helianthemoides*; 56 – *Convolvulus althaeoides*; 57 – *Sedum album*; 58 – *Juniperus phoenicea*; 59 – *Tetralinis articulata*; 60 – *Juniperus oxycedrus*; 61 – *Lomelosia stellata*; 62 – *Astragalus cruciatus*; 63 – *Calicotome spinosa*; 64 – *Hippocrepis scabra*; 65 – *Quercus ilex*; 66 – *Erodium glaucophyllum*; 67 – *Geranium rotundifolium*;

68 – *Ferula communis*; 69 – *Urginea maritima*; 70 – *Marrubium vulgare*; 71 – *Mentha rotundifolia*; 72 – *Rosmarinus officinalis*; 73 – *Salvia officinalis*; 74 – *Salvia verbenaca*; 75 – *Thymus ciliatus*; 76 – *Laurus nobilis*; 77 – *Malva sylvestris*; 78 – *Phillyrea angustifolia*; 79 – *Orobancha crenata*; 80 – *Chamaerops humilis*; 81 – *Papaver rhoeas*; 82 – *Globularia alypum*; 83 – *Aegilops geniculata*; 84 – *Ampelodesmos mauritanicus*; 85 – *Avena sativa*; 86 – *Avena sterilis*; 87 – *Aristida pungens*; 88 – *Briza minor*; 89 – *Bromus rubens*; 90 – *Ctenopsis pectinella*; 91 – *Hordeum murinum*; 92 – *Lolium multiflorum*; 93 – *Lolium rigidum*; 94 – *Lygeum spartum*; 95 – *Stipa tenacissima*; 96 – *Anagallis arvensis*; 97 – *Reseda alba*; 98 – *Ziziphus lotus*; 99 – *Tamarix gallica*; 100 – *Thymelaea hirsuta*; 101 – *Urtica dioica*; 102 – *Valeriana tuberosa*; 103 – *Peganum harmala*

Among annual species are several ruderal species (*Reseda alba*). Thus, woody, shrubby or herbaceous communities can be similar in their environmental conditions of habitat. According to Le-Houerou (1995), ovine and bovine overgrazing leads to the development of chamaephytes and their proportion increases as soon as degradation of pre-forestry environments occurs, as this biological type adapts better to summer drought and light than phanerophytes. Another gradient of degradation in steppe formations (*Stipa tenacissima* and *Lygeum spartum*) by the invasion of annual short-life species (therophytes), this therophytization is a form of resistance to climatic rigours. Thus, anthropization, grazing enriches the soil with nitrates and allows the development of ruderals, in particular annuals (Barbero et al., 1990).

The functional group B (32 species) is characterized by the total absence of phanerophytic species and the dominance of chamaephytes such as *Peganum harmala*, *Ferula communis*, *Laurus nobilis*. Hemipterophytes are represented by *Eryngium campestre*, *Telephium sphaerospermum* and finally four therophyte species: *Lomelosia stellata*, *Daucus carota*, *Avena sativa* and *Silene gallica*. We also noted the presence of species that dominate by their biomass such as *Lygeum spartum*. We observed the colonisation of certain species that mark anthropization (*Atractylis humilis*). In a multidimensional space functional group B occupies the lower right square. This region corresponds to the dry habitats with a high insolation level. Probably, dryness and intense lighting is a consequence of the presence of sparse grass cover. The reason for this can be seen in the variability of edaphic properties, which is reflected in increasing their acidity. Such edaphic conditions limit the significant development of vegetation. It should be noted that the overall level of soil nutrients is not high and does not act as a significant environmental factor, which is able to differentiate vegetation.

The functional group C (21 species) is dominated by thererophytes such as *Catananche caerulea*, *Bromus rubens*, etc. Geophytes are represented by *Asphodelus microcarpus* and *Urginea maritima*. Hemipterophytes are represented by *Valeriana tuberosa*. Among annual species *Convolvulus althaeoides* is a ruderal plant. Soil moisture regime leads to the differentiation of functional group (C) from the rest of the vegetation types.

The functional group D (8 species) is dominated by *Anacyclus cyrtolopidioides*, *Hypochaeris radicata*, *Silene vulgaris*. Therophytes are presented by *Geranium rotundifolium*, *Alyssum granatense*. *Ziziphus lotus* marks anthropization. Among annual species are several ruderal species (*Convolvulus althaeoides*, *Carduus nutans*). Plants develop along the edges of fields of cereals and fodder to the detriment of the natural species whose germination had been triggered by plowing. These crops play a role in the life of herders, since they represent a secondary financial contribution besides raising livestock.

Conclusion

The results obtained from this study show a change in the physiognomy of the studied flora caused by aridity of the climate (insufficiency and irregularity of precipitation) associated with the increase in anthropic activities (cutting, clearing, overgrazing and fires). There has been a degradation of forest and pre-forestry groups and their replacement by plant species adapted to climatic and anthropogenic stresses. There is a proliferation of species indicative of environmental degradation by anthropozoic agents such as *Ziziphus lotus*, *Urginea maritima*, *Ferula communis*, *Asphodelus microcarpus*, *Peganum harmala*, etc.

Finally, it can be pointed out from this contribution that the flora of the study area is in a regressive dynamic where several phenomena have left a strong imprint on these natural ecosystems. We suggest that it will be necessary in the future to make a follow-up survey, paying special attention to vulnerable species.

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