STRUCTURAL AND FLORISTIC FEATURES OF A *PINUS HALEPENSIS* MILL. FOREST ON COASTAL DUNE OF THE ZEMMOURI SAHEL (ALGIERS, ALGERIA)

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Abstract

The authors propose to contribute to the structural and phytosociological analysis of coastal forest of Zemmouri, a mixed natural forest of *Pinus halepensis* and *Quercus coccifera*. This stand is a young irregular grove, dominated by Aleppo pine with an average density of 406 stems/ha. Majority of trees is moderate sized, with an average dbh of 15-30 cm and height of 6-10 m, reflecting strong environmental constraints. Clear-cutting is a major cause of forest degradation as shown by the space factor of Hart-Becking, with a low dominant height and a weak basal area.
The phytosociological analysis permits to distinguish a plant community with *Querco cocciferae-Pinetum halepensis* belonging to *Querco-Oleion* alliance. The biological spectrum shows the predominance of phanerophytes, privileged by a subhumid and hot bioclimate. The summer drought stress led to a high proportion of Mediterranean element in chorological spectrum of the association. This forest is very threatened by an increasing human pressure. However, this natural mixed pine and oak forest is a vegetation structure more resilient to environmental accidents than artificial plantations. Its native species are mainly suitable for sandy soils and provide efficient stabilization of ancient dunes. So, the preservation of this type of coastal forest, corresponding to a habitat with ecological and biological value, is needed.

Keywords: *remnant forest - floristic analysis - structural features - Aleppo pine - anthropic pressure*

Résumé

Les auteurs proposent de contribuer à l'analyse structurale et phytosociologique de la forêt côtière de Zemmouri, un peuplement naturel mixte de *Pinus halepensis* et *Quercus coccifera*. Ce peuplement est une jeune plantation irrégulière, dominée par le pin d'Alep avec une densité moyenne de 406 pieds / ha. La majorité des arbres est de taille modérée, avec un dhp moyen de 15-30 cm et une hauteur de 6-10 m, en raison de fortes contraintes environnementales. La coupe en délit est une cause majeure de la dégradation de cette forêt, comme en témoigne le facteur d'espacement de Hart-Becking, avec une faible hauteur dominante et une surface terrière faible.
L'analyse phytosociologique permet de rattacher le groupement végétal à *Pinus halepensis* et *Quercus coccifera* à l'alliance du *Querco-Oleion*. Le spectre biologique montre la prédominance des phanérophytes, privilégiés par un bioclimat subhumide et chaud. Le stress de la sécheresse estivale a conduit à une forte proportion de taxons de l'élément méditerranéen dans le spectre chorologique de l'association. Cette forêt est très menacée par une pression humaine croissante. Cependant, la forêt mixte naturelle de pin et chêne représente une structure de végétation plus résiliente aux accidents environnementaux que les plantations artificielles. Ses espèces natives sont particulièrement adaptées aux sols sableux et fournissent une stabilisation efficace des dunes anciennes. Ainsi, la préservation de ce type de peuplement forestier, correspondant à un habitat à valeur écologique et biologique, est nécessaire.

Mots-clés : vestige forestier - analyse floristique - caractéristiques structurelles - pin d'Alep - pression anthropique

1. INTRODUCTION

Aleppo pine (*Pinus halepensis* Mill.) plays an important role in the ecology and landscape of the Mediterranean basin. This pioneer and undemanding species is easily regenerated and capable of colonizing very poor and degraded soils, due both to its intrinsic ability to colonize and to its effect in improving soils and microclimates, thus in turn favoring the growth of broadleaf Mediterranean species (*Quercus ilex, Q. coccifera*) within its stands [1]. It often

forms mixed stands consisting of an upper storey of *P. halepensis* and an understorey formed by one of the above species, usually evergreen or kermes oak [2].
The Mediterranean coastal dune geosystem is subject to many natural stresses and high human disturbance. This is the case of the coastal dunes of the Zemmouri's Sahel. The pioneer plant communities, settled on the white dunes, have been analyzed on the floristic point of view [3]. In this study, the authors propose to contribute to the structural and phytosociological analysis of the forest of Zemmouri, a mixed natural stand of Aleppo pine (*Pinus halepensis*) and kermes oak (*Quercus coccifera*) established on consolidated grey dunes. This forest is very threatened by an increasing human pressure. It represents one of the last remnants of coastal forest of the Algiers east coast, which needs an urgent conservation.

2. MATERIALS AND METHODS

2.1. Study area

The forest of Zemmouri's Sahel is localized in the department of Boumerdes and the municipalities of Zemmouri and Legata. It is situated between the longitudes 3°35' and 3°40' E and the latitudes 36°47'30" and 36°50'00" N, at 70 km east of Algiers. Its coast stretches over an area of 1,000 ha and a length of 12 km. This forest area is bounded on the north by the Mediterranean Sea, on south by the national road 24, to the east by the Wadi Isser and the west by the town of Zemmouri el Bahri (figure 1).

Figure 1. Situation of the study site: Sahel of Zemmouri

The forest of Zemmouri Sahel comprises two forest cantons with more or less artificialized vegetation:
• Canton of Sahel (447 ha), in the west part, where the vegetation is a natural stand of Aleppo pine (*Pinus halepensis*), with an undergrowth shrub (Kermes oak, pistachio mastic tree, oleaster tree, Phoenician juniper, etc.).

• Canton of Mandoura (553 ha), east part, occupied by reforestation, made during 1979, 1985 and 1986, based on fast-growing species (Aleppo pine, maritime pine, Canary island pine, Cypress, Eucalyptus, Acacias).

Geologically, it lies on marine sands of the Pliocene, which constitute the stabilized rear-dunes [4]. The terrain is more or less flat, with a slope not exceeding 5 % and the average altitude is 10 m.

Analysis of rainfall regime of Zemmouri shows an average annual precipitation of 714 mm [5]. About temperatures, the average maximum of hottest month is in August (M = 27.7 °C) and the mean minimum of coldest month is in January (m = 7.9 °C).

Summer drought is being felt from the month of May until August. According to the values obtained for the thermicity index (It = 393) and the annual ombrothermic index (Io = 3.4) [6], the forest of Zemmouri ranks in the subhumid thermomediterranean, with a hot thermal variant in winter *sensu* [7].

2.2. Methods

To analyze the stand structure in the pinewood of Zemmouri Sahel, we opted for systematic sampling, which it is easy to apply on the ground, given the homogeneity of environmental conditions (altitude, slope, and orientation), apparent homogeneity of the stand and the weak density of understorey.

For the stand inventory, the total number of sample units is 40 square plots of 20 m each side. They are distributed on the ground according to a systematic distribution through a grid with square network. In these plots of 400 m² each one, we measured some stand characteristics (tree density, diameter, basal area, average height, mixing ratio of Aleppo pine-Kermes oak). The diameter at breast height (1.3 m above ground) was measured for tree with dbh ≥ 7 cm (or circumference ≥ 22 cm) [8]. The total height of 2 trees closest to the center and the total height of the 2 big trees of the plot were measured using the Blume-Leiss. Basal area is a good indicator of competition at the tree layer. We counted the number of all trees per plot, thus a total of 636 stems for all the 40 plots.

By the Braun-Blanquet method [9], 21 floristic relevés are made in best preserved sites with relatively closed canopy, on a minimal area of 100 to 400 m² [10].

3. RESULTS

3.1. Stand structure and dendrological features

The pine forest studied shape a stand of uneven-aged structure [11]; this stand is a young irregular grove, dominated by the Aleppo pine. The density varies from 225 to 875 stems/ha with an average of 406.41 trees /ha ± 142. The coefficient of variation (CV) is 34.96 %, reflecting an irregularity of stand density. The Kermes oak, with trees of 5-6 m tall, is present with abundance in this forest and participates to stand density with an average of 120 stems/ha, i.e. 29.69 % of the population studied. It is represented with a stem's density, fluctuating between a minimum of 1.8 % and a maximum of 100 % exceptionally.

The mean diameter of Aleppo pine per plot varies between 8.37 and 42.05 cm, with an average of 21.12 ± 5.33 cm. The coefficient of variation (CV = 25.23 %) reflects a homogeneity of the stem's diameter of the stand. The distribution of trees according to diameter classes fits an exponential type curve (in i), with a positive skew (figure 2). This model reflects a lack of natural regeneration [8] of Aleppo pine, which is partly hindered by human impact (especially the clear-cutting recorded in all plots).

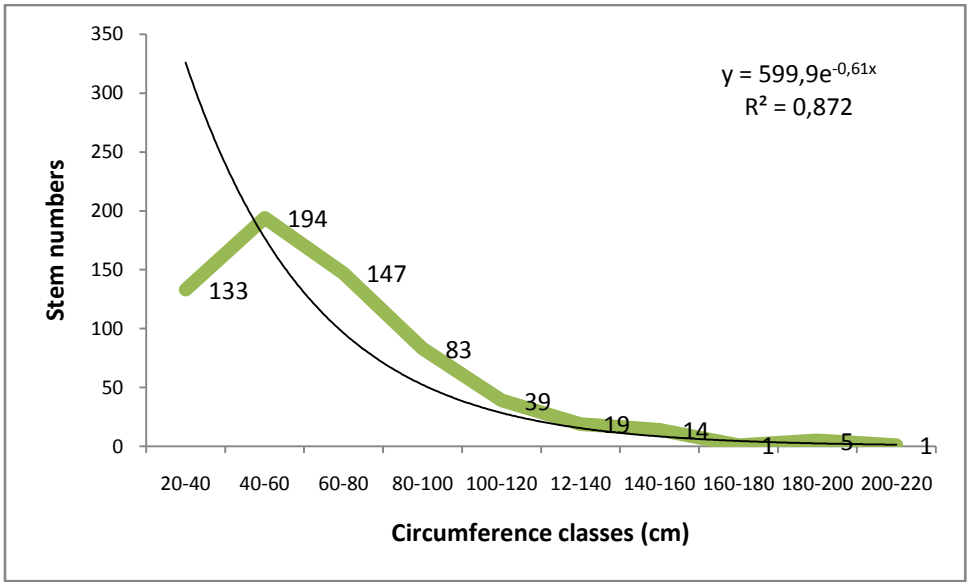

Figure 2. Distribution of stem numbers through circumference classes

The height of Aleppo pine trees ranges from 4.75 to 12.15 m, with an average of 8.11 m ± 1.5, with a low dominant height (9.68 m ± 1.7). The CV is very low (18.49 %), due to the homogeneity of the stand. A weak basal area of 14.3 ± 5.9 m²/ha is registered (CV = 41.4 %). We found that the majority of trees (63 %) have moderate size, with an average dbh of 15-30 cm and height of 6-10 m (table 1, figure 3), reflecting strong environmental constraints (oligotrophic soil in particular).

Table 1. Distribution of number of trees according to diameter classes (D cm) and average height (H m)

D (cm)/H (m)	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	Total
4-6	3	4		1	1				9
6-8		3	**8**	**5**	**10**	2			28
8-10		1	**6**	**10**	**10**	4			31
10-12			1	3		1	2	1	8
12-14					1	1			2
Total	3	8	15	19	22	8	2	1	78

Clear-cutting is a major cause of forest degradation, estimated to an average of 200 stems per hectare, otherwise 50 % of the current stand density. This forest is effectively much cleared, as shown by the Hart-Becking spacing index, which is HI = 55 % [2].

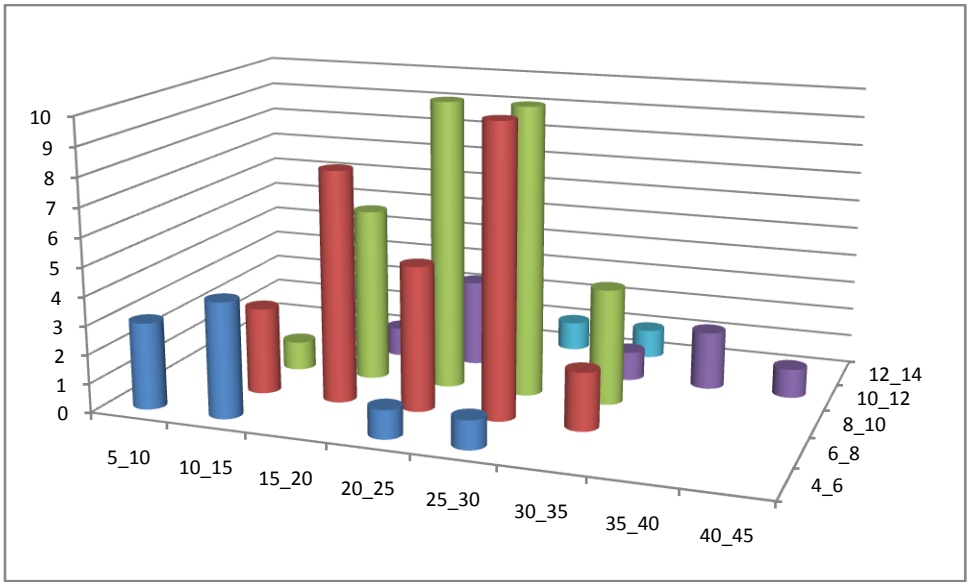

Figure 3. Distribution of tree numbers according to diameter classes and average height

3.2. Phytosociology and floristic diversity

Aleppo pine forest of Zemmouri matches to the "Coastal dune facies with *Juniperus turbinata" sensu* [12]. The analysis of 21 modern relevés made following the Braun-Blanquet approach, in well preserved sites and relatively closed canopy, permits to attach this plant community to the thermomediterranean alliance of *Querco-Oleion sylvestris* Barbero, Quézel & Rivas-Martinez *in* Rivas-Martinez, Izco & Costa 1986 (table 2). The transgressive species of the preforest mantle of *Juniperus turbinata* (*Juniperion turbinatae* Rivas-Martínez 1975) are well represented. The anthropic influence by a ruderalization process (human overcrowding, littering the forest …) results in proliferation of therophytes belonging to the *Stellarietea mediae* Tüxen, W. Lohmeyer & Preising *ex* von Rochow 1951 (*Geranium purpureum, Lagurus ovatus, Rumex bucephalophorus*…).

Table 2. *Quercus coccifera* and *Pinus halepensis* plant community

Numéro du relevé	13	14	12	15	6	16	18	19	2	3	4	10	5	11	7	1	8	9	17	22	24	Pr
Altitude (m)	10	10	10	10	10	10	10	10	15	10	10	10	10	10	10	15	10	20	10	20	5	
Pente (%)	20	5	0	20	0	10	0	10	0	0	5	15	5	0	10	0	0	0	0	0	10	
Exposition	N	N	-	S	-	S	-	S	-	-	N	S	N	-	W	-	-	-	-	-	S	
Surface du relevé (x 10 m²)	40	10	30	30	20	30	30	20	30	20	40	20	30	30	30	30	20	20	30	20	30	
R% strate arborée	60	60	70	60	80	60	90	70	60	60	70	60	80	70	80	70	60	50	90	60	60	
Nombre d'espèces	23	22	30	22	29	22	19	19	26	30	29	27	25	26	27	28	23	24	27	18	23	25
Pinus halepensis A	4	2	2	2	4		3	3	4	4	3	4	3	3	4	3	4	4	4	4	3	20
Pinus halepensis h			1	1	+					1	+	+	+			+						8
Quercus coccifera A	+	1	1	3	2	2	+	2	+	2	3	1	3	2	2	+	2	2	+	2	2	21
Quercus coccifera a	3	3	3	3	4	3	3	3	3	3	3	4	3	3	3	4	2	3	3	3	3	21
Caract. *Querco-Oleion sylvestris*																						
Rubia peregrina	1	1	1	1	1	2	1	2	2	1	2	1	1	+	1	1	1	1	1	2	1	21
Smilax aspera	2	2	+		3	1	2	2			1		+	+	1		1	+	+		+	15
Olea europaea subsp. *sylvestris A*					+				+	1	1				+	1	1	1				8
Olea europaea subsp. *sylvestris a*	+	+	1									1		1					+			6
Clematis cirrhosa	2	2	2	1															+			5
Myrtus communis											1	+	+			+						4
Transgressives du *Juniperion*																						

Juniperus turbinata a	2	2	2	1	1	+					1	2		+	1		1	1	+	1	2	15
Juniperus turbinata A			+						1	+						1						4
Juniperus turbinata h									+				+			+						3
Ephedra fragilis						1	+	2										1	+			5
Caract. des *Quercetea (etalia ilicis)*																						
Pistacia lentiscus	2	2	2	2	1	2	2	2	2	2	2	1	1	2	2	2	2	2	2	2	2	21
Phillyrea media	1	1	1	2	1	2	2	2	2	+	1	1	2	2	2	1	1	1	2	1	2	21
Asparagus acutifolius	1	1	1	1	1	1	2	2	2	2	2	2	1	2	2	1	1	2	2	1	1	21
Clematis flammula	1	1	1	1	1	1	1	1	1	1	2	3	2	2	+	2	1	+	1	1	1	21
Arbutus unedo a	2	2	2	2	1	2	+	+	2	2	2	1	2	2					+	+	+	17
Arbutus unedo A		+	+	1	1					1	1	1	1		+		+		+			11
Chamaerops humilis			1		+		1	+	+	+	+	+	1	+		+	+		1		1	14
Carex hallerana	+			1	1	1	1	1	1	2	+		1				1		1	1	2	14
Piptatherum miliaceum		+				1		1		1	1	1	+	1	+			+	1	1	1	13
Rhamnus alaternus									+	+	+	+	+	+							+	7
Centaurea africana var. *tagana*												+		+		+	1	1				5
Lonicera implexa			+								+				+							3
Jasminum fruticans					+											+						2
Bryonia dioica																+		+				2
Tamus communis															+							1
Polypodium cambricum											+											1
Prunella laciniata										+												1
Transgressives *Cisto-Lavanduleteea*																						
Cistus albidus	2	2	2	2	1	1			+	+	1	2	2	2	1	1	+	+	2	1	1	19
Cistus salviifolius	1	1	2	2	1	1			1	1	2	1	1		1		1		2	2	1	16
Lavandula stoechas			1																		+	2
Helichrysum stoechas										+					+			+				3
Compagnes																						
Geranium purpureum	+	1	+	1	2	2	2	1	1	2	2	1	+	2	2	2	2	2	2	2	2	21
Lagurus ovatus	1	2	1	2	1	2	3	2	+	1	1	+	1	1	1	+		+	1	1	1	20
Rumex bucephalophorus	1	2	2	2	+	1		1	+	+		+	+	+	1	+	+		1	1	2	18
Andryala integrifolia	+	+	+	1	+	2	1	1	+		+	+					+		1	2	+	15
Vicia sativa		1	+	1	1	+	+		1	1	1	1	+	1					+			13
Bellis sylvestris					1			2	+	+		1		+	+	+	1	+				10
Phalaris sp.									+		1	+	1	1	1	+		+				8
Solanum nigrum						+			+					+					+		+	5
Galactites tomentosa				+	+	1								+			+					5
Lobularia maritima	+		+								+					+		+				5
Chrysanthemum sp.	+				1										+	+						4
Plantago lagopus							+			+						+			+			4
Echium sabulicola							+									+						2
Reseda alba					+				+	+												3
Allium sphaerocephalon					+										+			+				3
Linum strictum	+		+																			2
Lotus creticus			+												1							2
Senecio vulgaris															+		1					2
Anagallis arvensis										+												1
Avena sterilis										+												1
Hypochoeris radicata																+						1
Mercurialis ambigua																		+				1
Ononis variegata			+																			1
Silene colorata														+								1

In terms of floristic diversity, this pinewood is notably poor; a total of 53 species is identified, with an average of 25 species per 100 m². The biological spectrum of the association shows the predominance of phanerophytes (including ligneous climbers), with Ph > Th > He > G >

Ch (figure 4), privileged by a subhumid and hot bioclimate (714 mm/year, m = 7.9 °C), despite four months of drought.
This summer drought stress led to a high proportion of Mediterranean element *sensu lato* in chorological spectrum of the association, 83 % of the flora (figure 5). There is particularly, as *Quercus coccifera*, often a tree of 5-6 m tall, a dozen typically Mediterranean sclerophyllous species: *Arbutus unedo*, *Olea europaea* subsp. *sylvestris*, *Pistacia lentiscus*, *Chamaerops humilis*, *Phillyrea media*, *Myrtus communis*, *Rhamnus alaternus* subsp. *alaternus*, *Jasminum fruticans*, *Clematis flammula*, *Clematis cirrhosa*, *Asparagus acutifolius*, *Smilax aspera* and *Lonicera implexa*.

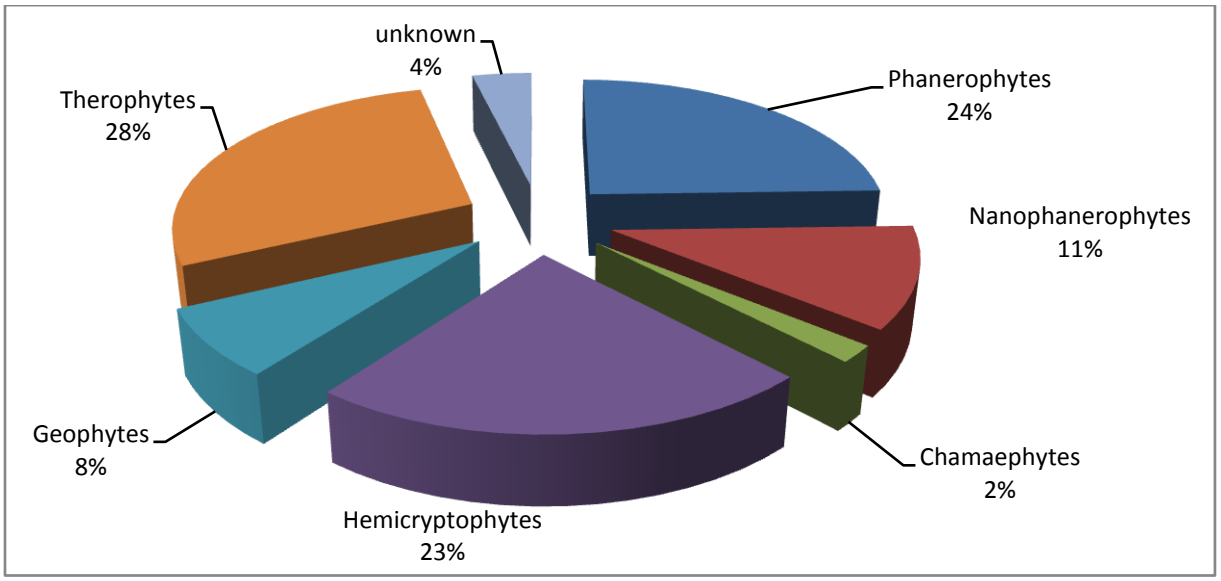

Figure 4. Biological spectrum of the plant community

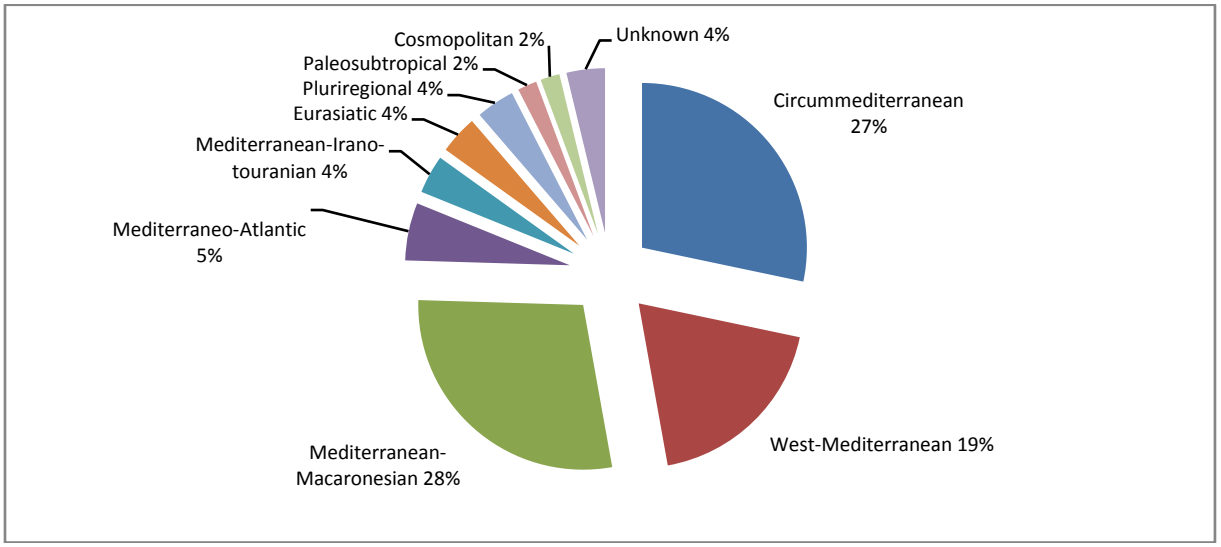

Figure 5. Phytochorological spectrum of the plant community

3.3. Anthropical degradation

Aleppo pine forest of Zemmouri undergoes many anthropic actions that negatively impact this vulnerable coastal forest ecosystem [3]:

- The encroachment of forest plots in peripheral areas to increase agricultural land;
- Grazing and trampling on;
- Illicit tree cutting;
- The illegal extraction of sand in the open forest, especially in Mandoura site;
- Emissions of pollutants (fertilizers, pesticides...) and various detritus;
- The overcrowding of the coast throughout the year and especially during the summer by thousands of holidaymakers;
- The voluntary and repeated fires (a sum of 270 ha burned by 21 wildfires during the period 1985-2010, with 96 ha in 1996, 44 ha in 2000, etc.).

In addition to the burnt areas, sometimes irreversibly, the fragmentation of the forest is due to several expropriations:

- A racecourse was built in 1989 and covers an area of 87 ha,
- A Park, located in the forest of Zemmouri, was managed on 45 ha, for recreation by the municipality (hotels, campsites, a dozen kiosks, shops, several restaurants and cafeterias, spaces rest and play areas...),
- An area tourism expansion (ZET) of Zemmouri East (tourist village of 295 bungalows) has been established on 34 ha of a burnt land after a fire in 1988.

4. CONCLUSION

Aleppo pine forest covers nearly 11 % of the eastern coast of Algiers, between Cap Blanc and Cap Bengut [13], and represents one of the last remnants of coastal forest in Algiers. Subjected to high disturbance and human impact, it may disappear in the medium term, seriously threatened by the increasing of an anarchic tourism.

The natural mixed pine and oak forest of Zemmouri is a vegetation structure more resilient to environmental accidents than artificial plantations (pines, eucalyptus and acacias) [14]. Its native species are mainly suitable for sandy soils and provide efficient stabilization of ancient dunes. These considerations argue for the preservation of this rare type of habitat, with high patrimonial value, which is a good example of multifunctional forest.

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