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Vascular flora analysis in the Southern part of Chott El Hodna wetland (Algeria)

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Abstract. The southern part of Chott El Hodna (M'Sila province - Algeria) wetland belongs to mediterranean arid bioclimatic stage with mild winter. During the period 2009-2013, an inventory of the natural vegetation took place in this area where 79 floristic samples were conducted along two transects from north to south and from east to west. We found 116 species, distributed in 85 genera belonging to 29 botanical families. The Magnoliopsida have 27 families and 68 genera and the Liliopsida have only 02 families and 17 genera. There are six families whose are best represented by 65.52% of the total flora (Poaceae, Asteraceae, Fabaceae, Chenopodiaceae, Brassicaceae and Caryophyllaceae). This flora contains 20 endemic taxa including 8 rare species. It has the following biological spectrum: annuals (therophytes): 60.34% and perennials: 36.66% (chamaephytes: 18.10%, hemicryptophytes: 11.20%, phanerophytes: 6.03% and geophytes: 4.31%). This is a characteristic of arid habitats. The numerical analysis of vegetation by using the Sørensen's similarity index and the Detrended Correspondence Analysis (DCA) resulted in the individualization of three major groups of samples that reflect different environmental conditions and specific enough of the study area. The vegetation appeared much adapted to the environment. The preservation of this habitat and flora must register in emergency concerns.
Key Words: vascular flora analysis, endemic species, Chott El Hodna wetland, similarity, DCA, Algeria.

Introduction. The natural components of the ecosystem are defined as the physical, biological or chemical, such as the environment, water, flora, fauna, nutrients and the interactions that exist between them (Davis 1996). The flora of a geographical area is the most important biotic component (Ozenda 1982). It is an expression of ecological conditions there. Myers (1990) and Médail & Quézel (1999) show that the Mediterranean region, including our study area, is one of the world's major centers of plant diversity, where 10% of higher plants can be found in only 1.6% of the Earth's surface. Similarly, Myers et al (2000) consider that the Mediterranean countries hold almost 4.5% of the world's endemic flora.

The studied area is part of the great watershed Hodna (Hadjab 1998; Le Houerou 2009). This is an athalassic salt lake. It is formed by a sebkha and a Chott. Sebkha is the central area dominated by water and devoid of vegetation due to high salt concentrations. Chott is the surrounding area which forms a ring of vegetation around water. This vegetation is steppic and mainly composed of salt-tolerant, perennial and succulent species (Kaabeche et al 1995). Chotts and sebkhas have a seasonal water regime. They dry up in summer and are re-flooded by water in winter.

The vascular flora of the southern part of this wetland is a part of the steppe vegetation of the Hodna (Le Houerou 1995). According to Kaabeche (1990) this area, from the biogeographic belonging, is a Mediterranean region with two sub-regions of Eu-Mediterranean (Maghreb-Mediterranean and Mediterranean-steppic areas) and Sahara-Arabian (Sahara-Mediterranean area).

The plant richness is due to the geomorphological diversity of the region and has resulted in a wide range of local climates (Médail & Myers 2004).

This heritage is currently under threat of degradation due to a combination of several natural factors (especially recurrent droughts and arid climate) and anthropogenic activities including overgrazing and land clearing. This regressive dynamic situation of the natural vegetation has prompted us to take stock of what exists in order to decide on the future floristic's degradation or loss which may occur in that particular area for the preservation of the flora. Management and conservation of natural environments and especially wetlands of international importance implies knowledge of flora and especially those endemics or rare those reflect the importance of the local or regional biodiversity. The precise knowledge of the vegetation of a region is the essential foundation and starting point for any attempt to conservation (Quézel 1991). The inventory and analysis of the natural vascular plant of our study area is necessary to know the overall composition of existing taxa, flora diversity and chorology species because this area belongs to a wetland that has an international importance and must be preserved.

Material and Method

Study area. Chott El Hodna is situated in northeastern Algeria (Figure 1). It is one of the largest Chotts of Algeria with an area of 362,000 ha (DGF 2002). It is a wetland of international importance under the Ramsar Convention. It was classified such as in 2001 (DGF 2002). According to Emberger (1955) in Le Houerou (1995) and depending on weather data from the meteorological station of Boussaada (459 m alt., 35°20' lat. N & 04°12' long. E), the south of Chott El Hodna is located in a mediterranean arid bioclimatic stage with mild winter (Q_2 = 18.43, m = 4.3°C, M = 39.4°C, P = 190.9 mm and seasonal rainfall regime is Autumn-Spring–Winter-Summer). Geologically, the study area contains deposits of alluviums of the Quaternary. It is a part of a semidesert sandy region with the presence of sand dunes (Mimoune 1995).

Our study area in the southern part of Chott El Hodna wetland present two environments: the first is the M'Cif wadi and the second is the Chott near the sebkha area.

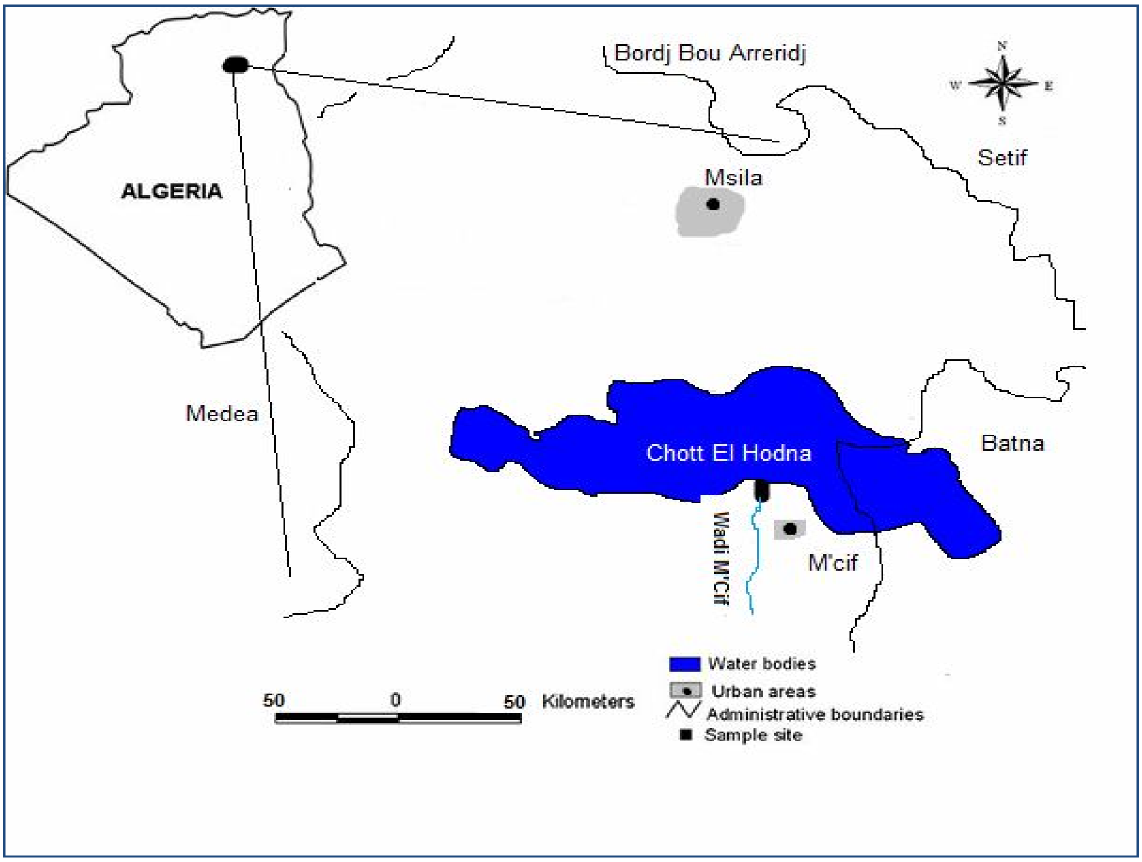

Figure 1. Location of study area (original drawing).

***Sampling and data analysis**.* We conducted a non-probability systematic sampling in a repetitive mode represented by online sections crossing the existing vegetation belts in two different sites: wadi and Chott.

The first site of the North-South transect, concerns the banks of the M'Cif wadi: East Bank and West Bank. The second East-West transect site concerns the Chott in its southern part of Chott El Hodna.

The distances between the floristic samples are irregular. They range from 100 to 180 m along the lines of the abovementioned directions.

Between 2009 and 2013 and during Springs seasons, floristic samples were conducted according to the method of minimum area (Hammada 2007). This area is that of the floristic sample (Hamel et al 2013). This is the Braun-Blanquet method (Guinochet 1973). It involves the taking of all plant species in a well-defined surface and where each species was assigned by a semi-quantitative coefficient: abundance-dominance (Gillet 2000). The minimum area expresses the necessary and sufficient surface for a floristic sample (Lacoste & Salanon 2005). Colin (1970 in Frontier 1983) defined the sample (floristic releve) as a fragment taken to judge the whole because it contains almost all of the species that can be found in the study fragment. The surface of the floristic sample depends on climatic and stationary conditions. The number of annuals (therophytes) also depends of these same conditions (Djebaili 1984). In the steppe communities several researchers used: Djebaili (1978) 100 m², Kaabeche (1990) 16 m², Ayad et al (2013) 16 to 20 m² and Bouabdallah (1992) 16-256 m². For our part this surface varies from 20 to 70 m². It should be noted that it is rarely possible to identify all individuals in a community (Magurran 1988).

The collected samples were identified and determined by the use of: Newflora of Algeria and southerly desert regions: Quezel & Santa (1962, 1963) and Sahara Flora: Ozenda (1983). The taxa nomenclature used is that of Quézel & Santa (1962, 1963), however, when the taxon is indicated by the mere mention of "endemic" (noted End.), it is considered an algerian endemic according to Véla & Benhouhou (2007). The mention of rarity in the Quézel & Santa (1962, 1963) flora is by a single index. This index has four levels ranging from "extremely rare" (RRR) to "quite rare" (AR) (Vela & Benhouhou 2007; Medjahdi 2010). Only three levels of rarity are retained in our work. They correspond to the relative scarcity of our taxa: AR - quite rare; R – rare, and RR - very rare. Regarding biological types used in this study is that of Raunkiaer (Emberger 1966).

For the numerical analysis of the vegetation two techniques were used. First, the similarity index where several options exist and to assess the floristic similarity of two lists of species or two sites or statements of study (Kouassi et al 2010). We chose the Sørensen-Dice index. It uses binary data of species (Gower 1971 in Johnston 1976; Hill & Gauch 1980; Duarte et al 1999; Dalirsefat et al 2009; Faye 2010; Kallio et al 2011; Marcon 2013; Hammer 2015). Semi-quantitative coefficient of abundance-dominance was transformed into qualitative presence-absence coefficient. Comparing the samples are done in the presence-absence (coded 0 or 1), without species weigh, according to abundance-dominance (Gillet 2000).

Secondary, and for a deeper analysis of our results, we also used the Detrended Correspondence Analysis (DCA) because not prone to arch effect and data compression (Hill & Gauch 1980; Minchin 1987; Bouxin 2014) samples to be unevenly spaced along the axis 1. DCA ordinations perform better with simulated data than do correspondence analysis (CA) and reciprocal averaging (RA) ordinations (Holland 2008). This technique works well on vegetation data (Hill & Gauch 1980). In the DCA graph, environments where plant composition or floristic samples, translate the same environmental conditions (Khaznadar et al 2009). These techniques used (Similarity index and DCA) were calculated through the PAST free program (Paleontological Statistics) Version 3.05 (1999-2015).

Results and Discussion. A total of 79 samples were thus made during the period mentioned above. From this, the samples are as follows:

- the banks of M 'cif wadi contains 42 samples with 21 samples/bank;
- the south of the Chott totals 37 samples.

Botany and chorology

Taxonomic overview. The qualitative floristic analysis (family, genus and species) is made from the floristic inventory list. We obtained 116 species, distributed in 85 genera and 29 botanical families (Table 1). The Magnoliopsida, with 27 families and 68 genera representing 93.10% while the Liliopsida present only two families with 17 genera and representing 6.90% of the total flora. The six most important families are almost two-thirds of the taxa present is 65.52% of the total flora. These families are: Gramineae with 19 species, representing alone 16.38% of the inventoried flora; the other families are Compositae (17 species), Fabaceae (14 species), Chenopodiaceae (12 species), Brassicaceae (8 species) and Caryophyllaceae (6 species), containing respectively 14.65%, 12.07%, 10.34%, 6.90% and 5.17% of the species of the flora. Similarly, and in a in a similar area, Zedam et al (2010) found that the richest families in species were Gramineae and Compositae. The rest of the families (23 families) have each only one, two or three species.

Chorology. Using Quézel & Santa (1962, 1963), Ozenda (1983) and Dobignard & Chatelain (2010, 2011, 2012), the chorological origns of the species in our study area are 36 and they are presented in Table 1.

Table 1

Chorological origin species in the southern part of Chott El Hodna wetland

Chorological origin	*Number*	*Total of species*	*Percentage rate (%)*
Mediterranean	1	23	19.83
Sahara Sindien	1	11	9.48
Endemic North African	1	9	7.76
Mediterranean-Sahara Sindien	1	7	6.03
Cosmopolitan	1	6	5.17
Mediterranean-Iran-Turan	1	5	4.31
endemic Saharan	1	5	4.31
Mediterranean-Sahara	1	4	3.45
Paleo-temperate	1	4	3.45
Eurasian	1	4	3.45
Sahara	1	3	2.59
endemic Algerian	1	3	2.59
The 24 remaining sources	24	32	27.58
Total	36	116	100

The most important chorological origin (12 of 36) in our study area contained about three quarters (72.42%) of total taxa. The Mediterranean element has 19.83% of the plants identified who demonstrates the membership of this biotope at the Mediterranean region (Kaabeche 1990). In our investigation, despite the presence of other chronological origins and the dominance of the Mediterranean vegetation, Kaabeche (1995, 1996, 1998) denotes the biogeographical situation rather peculiar of this area between the Mediterranean region in the north and the Sahara-Arabian region in the south. The least chronological origins of species (32 species) are usually only singleton (those represented by a single individual) which seems reasonable (Magurran 2004, 2005).

Endemism and rarity. Referring to the new flora of Algeria and the southern desert regions of Quézel & Santa (1962 & 1963) and the Flora of Sahara of Ozenda (1983), the vegetation of our study area contains 20 endemic taxa (17.24% of the total species identified). The existence of 08 endemic and rare species (Table 2) shows the ecological value of important floristic regions (Fennane 2004). This endemic flora has the following biogeographical origins: North African: 9 taxa with 1 taxon AR, 1 taxon R and 2 taxa RR; Saharan: 5 taxa with 1 taxon AR and 1 taxon R; Algerian: 3 taxa with 1 taxon AR; Algerian-Tunisian: 2 taxa with 1 taxon R; Algerian-Moroccan: 2 taxa.

Table 2

Species endemism and rarity according to the botanical families in the southern part of Chott El Hodna wetland

Species	*Botanical families*	*Chorological origin (endemism)*	*Rarity*
Astragalus armatus ssp *tragacanthoides*	Fabaceae	North African	RR
Astragalus gombo	Fabaceae	North African	
Melilotus macrocarpa	Fabaceae	North African	RR
Hedysarum carnosum	Fabaceae	Algerian-Tunisian	R
Zygophyllum cornutum	Zygophyllaceae	Algerian-Tunisian	
Lycium arabicum	Solanaceae	Saharan	
Cistanche violacea	Orobanchaceae	North African	AR
Anthemis monilicostata ssp *stiparum*	Asteraceae	Algerian-Moroccan	
Anacyclus cyrtolepidioides	Asteraceae	North African	
Enarthrocarpus clavatus	Brassicaceae	North African	
Ammosperma cinereum	Brassicaceae	Saharan	AR
Thymelea microphylla	Thymeleaceae	North African	
Limonium cymuliferum	Plumbaginaceae	Algerian	AR
Limonium pruinosum	Plumbaginaceae	Saharan	R
Limoniastrum guyonianum	Plumbaginaceae	North African	R
Frankenia thymifolia	Frankeniaceae	North African	
Silene arenarioides	Caryophyllaceae	Algerian	
Herniaria mauritanica	Caryophyllaceae	Algerian	
Euphorbia guyoniana	Euphorbiaceae	Saharan	
Scrophularia saharae	Scrophulariaceae	Saharan	

AR - quite rare; R – rare; RR - very rare.

Biological types. The biological types were determined as they appear in the vegetation studied on land (Emberger 1966). In some cases, the biological type is not detectable and it took complement through the exploitation of other flora and references such as Dobignard & Chatelain (2010, 2011, 2012). All of the identified species were grouped by biological type as follows: therophyte (70 species), chamaephyte (21 species), hemicryptophyte (13 species), phanerophyte (7 species) and geophyte (5 species) (Figure 2).

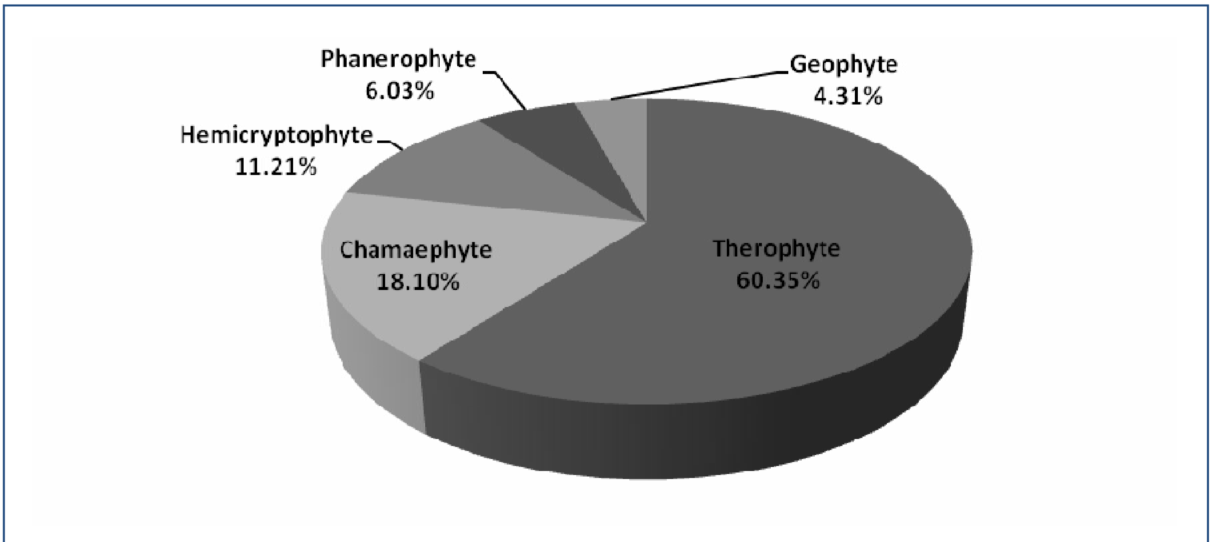

Figure 2. Distribution of biological types in the study area.

The most dominant life form is therophyte. It represents 60.35% of all species. The second important is chamaephyte with up to 18.10% of total plants. The hemicryptophyte, phanerophyte and geophyte have respectively: 11.21%, 6.03% and 4.31% of the total. This fact reflects a characteristic of arid habitats where water and heat stress, omnipresent in our study area, are factors that control the growth and geographical distribution of plants (Le Houerou 1989).

Contrary to what was reported by Killian (1953), where annual species are poorly represented in the flora around Chott El Hodna, in the steppe formations, the therophyte predominate over other life forms (Kaabeche 1990, 1995; Khaznadar et al 2009). The abundance of therophyte can be explained by the strong presence of seasonal habitats for the development of rapid annual germination and growth (Hammada et al 2004). Hammada et al (2004) and Hammada (2007) report that the dominant terrestrial flora found in Morocco's wetlands are annuals (therophytes). This biological type has a short development cycle, easily and quickly colonizes many environments. The other types can not move anywhere because of their requirements.

The plant richness is due to the geomorphological diversity of the region and has resulted in a wide range of local climates (Médail & Myers 2004).

Numerical analysis of vegetation

Similarity index. Similarity indices were calculated between all the pairs of samples. One useful property of a similarity index is that it increases linearly from some fixed minimum to some fixed, finite maximum (Wolda 1981). High values are interpreted as reflecting low beta diversity: high similarity (Koleff et al 2003).

Taking into account the Sørensen's similarity between samples and according to Figure 3, the cluster analysis takes into account the variation of species and thus clearly separates the different microhabitats or study sites (Jenny et al 1990).

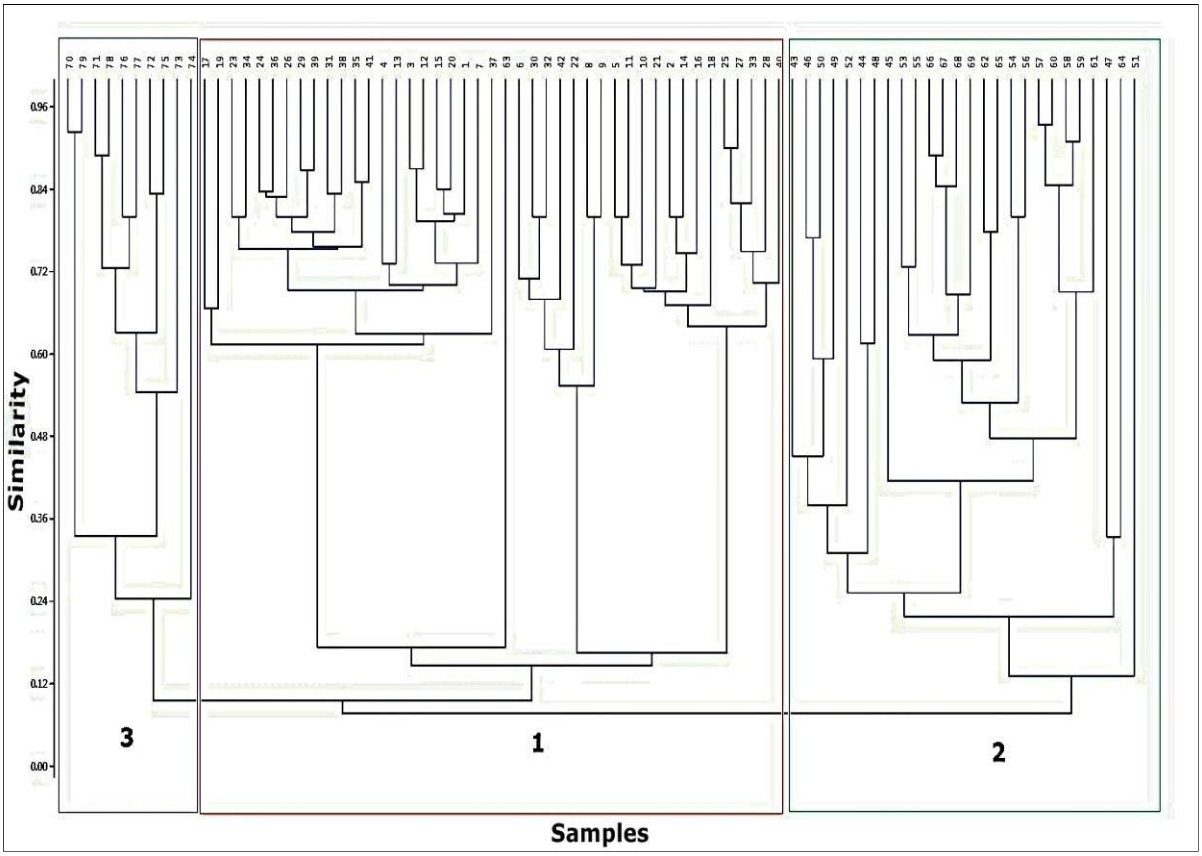

Figure 3. Sørensen's similarity index of samples.

Taking into account the values of the similarity in the similarity matrix between sample pairs, they are fairly consistent throughout. They vary as follows: for the group of samples 01 to 42 - 0.87 (3; 12), 0.83 (1; 3), 0.81 (3; 15), 0.80 (5; 11); for the group of samples from 43 to 69 - 0.90 (66; 67), 0.83 (57; 60) and (67; 68) and 0.76 (53; 55); and in the end for samples group 70 to 79 - 0.80 (70; 79), 0.74 (72; 75) and (76; 78) and 0.69 (71; 78). On the other hand the graph similarity of samples (Figure 3) shows three major groups: a first group (1) encompassing samples 01 to 42 in the center and it concerns the samples conducted in the wadi banks. A second group (2) is marked by samples from 43 to 69 and is related to the area of fine texture and apparent surface salinity. A final set (3) is highly individualized samples 70 to 79 and covers performed on sandy soil.

The similarity showed the existence of soils difference (salinity) between stations and led to a sharp difference of vegetation. The samples group subservient to the relatively saline soil and fine texture are characterized by relatively salt-tolerant species: *Halocnemum strobilaceum* (Pall.) M. B., *Suaeda fruticosa* L. and *Frankenia pulverulenta* L. (Quézel & Santa 1962, 1963; Ozenda 1983). Bouabdallah (1992) and Géhu et al (1993) report that *H. strobilaceum* belongs to halophilous plant community.

Also Kaabeche et al (1995) report that *H. strobilaceum* and *F. pulverulenta* are halophilous plants. The psamophilous group species on sandy soil represented by *Aristida pungens* Desf., *Retama retam* Webb and *Cutandia dichotoma* (Forsk) Trab are encountered in sandy arid areas (Djebaili 1984). Similarly Ward et al (1993) report that *R. retam* is a typical plant found in sandy habitats of the Negev Desert in the Middle East. The group records of the wadi banks encompasses a wide variety of species but not characteristics of the two firsts groups. It is an environment drained by unsalted water. This is an area of vegetation which belongs to an anthropized area (area pastured and plots cultivated). Among the species found in this site: *Hordeum murinum* L., *Lolium multiflorum* Lam. and *Anagallis arvensis* L. The presence of these plants indicates disturbed environments.

Detrended correspondence analysis (DCA). The multivariate analysis techniques can transform a table "samples/species" data to the gradient search (Bouxin 2014). The bundling of records based on the presence/absence leaves us visualizes groups based on species composition and the factors responsible for this distribution. According to Figure 4(a), the main gradient in samplings as revealed by the axis 1 in DCA ordination spanned of three groups situated near to themselves. A first group (A) encompassing samples 43 to 69 in the right of the axis and it is related to the area of fine texture and apparent surface salinity. A second group (B) in the center of the axis is marked by the samples 1 to 42 conducted in the wadi banks and in the end a final set (C) individualized samples 70 to 79 and covers performed on sandy soil which are localised at the left of the axis. This gradient means that the axis shows a really evolution of fine texture with salinity area which is opposed a sandy area with less salinity. The gradient revealed by the axis 2 in DCA graph, mean an evolution down to up of soil moisture. The Figure 4(b) reveals the vegetation characterised by species composition such as psamophilous plants like: *Neurada procumbens* L., *Cutandia dichotoma* (Forsk) Trab and *Bassia muricata* (L.) Asch in the left of the axis. Halophilous plants in the right of the axis such as: *Limoniastrum guyonianum* Dur., *Salicornia arabica* L. and *H. strobilaceum*. Between these two species composition there is many species belonging to an anthropized area: *Polygonum aviculare* L., *Cynodon dactylon* (L.) and *Malva sylvestis* L. Agricultural activities generate a significant decline in biodiversity (Daget & Poissonet 1997) and a trivialization of the flora of the need to conserve species through management of the most sensitive natural environments (Verlaque et al 2001).

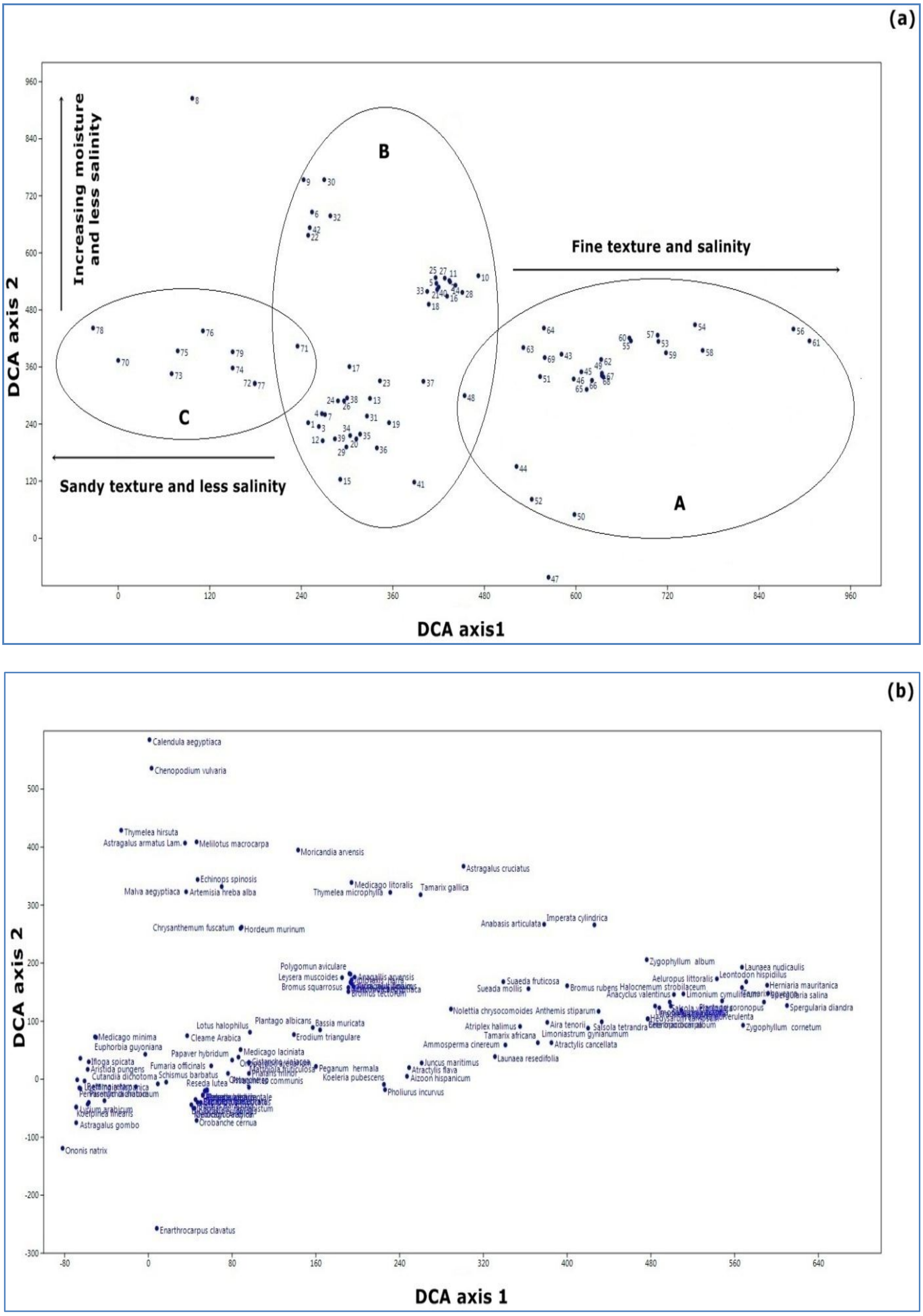

Figure 4. DCA ordination of the 79 samples and species in 1 and 2 axis. a. Site affiliation of samples. b. Positioning of the 116 species found in the samples.

Conclusions. The Mediterranean region, including our study area, is one of the world's major centers of plant diversity. The geographical position of Algeria between the Mediterranean in the north and the Sahel in the south has a host of wetlands of international importance under Ramsar Convention which Chott El Hodna is a part. It is an athalassic salt lake. It is formed by a central water area devoid of vegetation due to high salt concentrations and surrounding by plants. The vascular flora of the southern part of this wetland is a part of the steppe vegetation of the Hodna.

The inventory and analysis of this type of flora in this environment is essential to know the overall composition of existing taxa, plant diversity, biogeography and ecology of the species. A total of 79 samples were thus made during spring seasons in the period 2009-2013. From this, the samples are 42 in the banks of M'cif wadi and 37 in the south of the Chott. A total of 116 species were found. The qualitative floristic analysis gives 85 genera and 29 botanical families. The six most important families of the taxa have 65.52% of the total flora. They are Gramineae, Compositae, Fabaceae, Chenopodiaceae, Brassicaceae and Caryophyllaceae.

Biogeographically, our study area is situated between the Mediterranean region in the north and the Sahara-Arabian region in the south. The most important chorological origin is the Mediterranean element. This result demonstrates the membership of this biotope at the Mediterranean region. There are 20 endemic taxa whose have revealed the existence of 08 endemic and rare species. The most dominant biological type is the therophyte compared to other types. This fact reflects the characteristics of arid habitats where water and heat stress are factors that control the growth and the geographical distribution of plants.

The numerical analysis of vegetation by using the Sørensen’s similarity index and the Detrended Correspondence Analysis (DCA) resulted in the individualization of three major groups of samples. A first group encompassing samples and it concerns the samples conducted in the wadi banks which contains vegetation belongs to an anthropized area (area pastured and plots cultivated). A second group is marked by samples related to the area of fine texture and apparent surface salinity where salt-tolerant species are. A final set is highly individualized covers performed on sandy soil characterized by psamophilous species. The vegetation appeared much adapted to the environment that reflect different environmental conditions. The axis 1 in DCA graph means a gradient that a really evolution of fine texture with salinity area which opposed a sandy area with no much salinity. The gradient revealed by the axis 2 in DCA graph, mean an evolution down to up of soil moisture. The preservation of this habitat and flora must register in emergency concerns. Our study area is vulnerable especially against destructive human actions (plowing, burning, overgrazing and uprooting) where the work of backup and preservation of this area should be maintained because of its membership in the wetland of Chott el Hodna.

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