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The influence of environmental factors on the distribution and composition of plant species in Oued Charef dam, northeast of Algeria

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Abstract. *Moualki N, Boukrouma N. 2020. The influence of environmental factors on the distribution and composition of plant species in Oued Charef dam, North East of Algeria. Biodiversitas 22: 346-353.* Identification of the primary factors that influence the ecological distribution of species groups is important to managers of Oued Charef dam in northern Algeria. This study aimed to identify main ecological species groups, describe the site conditions associated with these species groups, and the relationships between environmental factors and the distribution of ecological species groups using Ward's cluster analysis for classification and principal component analysis (PCA). For this purpose, 50 plots (200 m^2 each) were sampled using the Braun- Blanquet method. Soil samples were collected and analyzed to study soil properties. Multivariate analysis methods were used to classify and determine the relationship between species composition and environmental factors and to recognize ecological species groups. The *R* i386 (version 4.0.3) software was used for data analyzing. Ward's cluster analysis when applied on terrestrial species data gives three groups distinctly distributed on ordination plan. In cluster groups of terrestrial species Group (1) is dominated by *Daisies chrysanthemum*, Group (2) by *Cynodon dactylon L,* and Group (3) dominated by *Fumana thymifolia*. The groups of terrestrial species are readily superimposed on PCA ordination plane. The most important environmental factors associated with terrestrial species composition in Oued Charef dam communities were conductivity (EC), FSA, FSI, clay, salinity, phosphorus (PO_4), TN (nitrogen), nitrates (NO_3), and nitrites (NO_2). While among the edaphic factors only pH showed a negative correlation to plant species this may due to the anthropogenic disturbances however further studies are needed to explore the rest of parts of the said regions. This study gives important insights on ecological relationships between plant biodiversity and soil chemical in a primary wetland ecosystem in northeast of Algeria.

Keywords: Species groups, relationships, multivariate analysis, terrestrial species, edaphic factors

INTRODUCTION

Wetlands ecosystems are known for having the highest plant communities on the planet (Skeffington et al. 2006; Hebb et al. 2013; Wetser et al. 2015). These plant communities are the key components of this ecosystem function and stability. It is thought that higher plant communities in wetlands are caused by factors such as high temperature, high humidity, and high solar radiation all year round which favor the growth of a large number of species (Givnish 1999). Although the main causal factors of plant communities are related to environmental factors, it is important to understand what is happening at the microhabitat level. Do soil variables have any effects on plant communities in wetlands?

Many studies have examined relationships between plant communities and soil variables (Dekeyser et al. 2003; O'Connell et al. 2012; Williams and Ahn 2015). These works suggested that soil conditions are the main environmental factors affecting wetland plant communities, namely soil nutrients including nitrogen, phosphorus, and organic carbon (Li et al. 2010; Zheng et al. 2013; Jager et al. 2015; Wang et al. 2016). Wetland vegetation can effectively absorb nutrients from the surrounding soil. Kang et al. (2002) found that soil environmental factors have important effects on plant growth and reproduction. In a more specific study, Janssens et al. (1998) looked at the relationship between plant biodiversity and different soil chemical factors in numerous wetlands ecosystems. They found a positive relationship between plant biodiversity and the concentration of extractable phosphorus and nitrogen in soil Janssens et al. (1998). Recently, Dybzinski et al. (2008) investigated the effects of soil variables in plant species diversity in the grassland ecosystem of Minnesota in the United States. They found that the different soil environmental factors determined the wetland vegetation pattern and process (Dybzinski et al. 2008). Much research has been done on the relationships of plant biodiversity with soil variables in different ecosystems, temperate forests, tropical forests, and agroecosystems. On the other hand, there is a lack of research and data available about this correlation in wetland ecosystems. In this study, we gathered baseline data for the relationship between plant biodiversity and soil variables in Oued Charef dam in northeast of Algeria. This paper deals with the vegetation aspect of a wider study that aimed to classify and evaluate the wetland with respect to soil factors as well as plant communities. We tested the hypothesis that there are some relationships between various plant biodiversity measurements and soil chemical factors.

MATERIALS AND METHODS

Study area

The study was conducted in an arid-hot valley, dam Oued Charef (36° 5'22.91"N 7°23'20.78"E, alt. 920 m a. s. l., area: 1010 ha), located in souk Ahras Province, northeast of Algeria (Figure 1). The dam height is 960 m, the normal storage water level is 752 m, the water area is about 1287.18 ha, and the total reservoir capacity is 229.85 Hm^3. The annual precipitation varies in the range 158-480 mm with more than 70% concentrated in the winter. The mean annual temperature ranges from 11.9 to -22°C. Even though the wetland is comprised of aquatic plants, it is surrounded by cereal crops consisted of Chenopodiaceae (*Atriplex halimus, Atriplex patula, Salicornia fruticosa, Salsola fruticosa, Suaeda fruticosa*), Brassicaceae (*Mauricandia arvensis, Matthiola fruticulosa, Diplotaxis éricoïdes, Capsella bursa-pastoris*) (Boukrouma 2017).

Data collection

Vegetation sampling procedures

Initially, to general reorganize of study area and investigate plant vegetation, a field survey was done. Based on the primary study, major plant species and species selected and sampling were done with a systematically randomized method. In each species site, 3-5 transects with a length of 200 m each including 10 plots of 1 m were established.

The area of plots in each plant type was determined by the mini-mum surface method using a nested plot technique and area/species curves (Mueller-Dombois and Ellenberg 1974). The 50 homogenous plots were placed systematically to determine plant distribution and diversity. The vegetation of research plots was surveyed according to Braun-Blanquet (1964). Cover estimates were made for all plant species. The source of the nomenclature was: Martincic et al. (1999) for vascular plants, Coreley et al. (1981), Grolle and long (2000) for liverworts. According to the phytosociological units, the source of characterization of the plant species was Oberdorfer (1983, 1992). From all the 50 research plots we took soil samples at depths of 0-20 cm from these samples we produced 50 homogeneous composite soil samples.

Soil analysis

The soil samples were air-dried at room temperature and passed through a 2 mm sieve. The weight of fine fraction (<2 mm) in each soil sample was determined and kept for laboratory analyses. Soil samples of each depth were mixed before analysis to reduce soil heterogeneity.

pH was measured using a glass electrode pH meter (McLean 1982), conductivity with electric conductivity meter, (Rhoades 1982), organic matter by Walkley and Black's method (Nelson Sommers 1982); phosphorus by Olsen method (Olsen and Sommers 1982); Carbonate by dry combustion (Iso 1994, see also Nelson and Sommers 1982) and exchangeable cations (Potassium, Magnesium, Calcium, and Sodium) were analyzed with atomic absorption spectrophotometry using a barium chloride solution (Gillman 1979). On the basis of these measurements, we also calculated the C/N ration. Nitrogen content was determined by the Kjeldahl Method (Bremner and Mulvaney 1982).

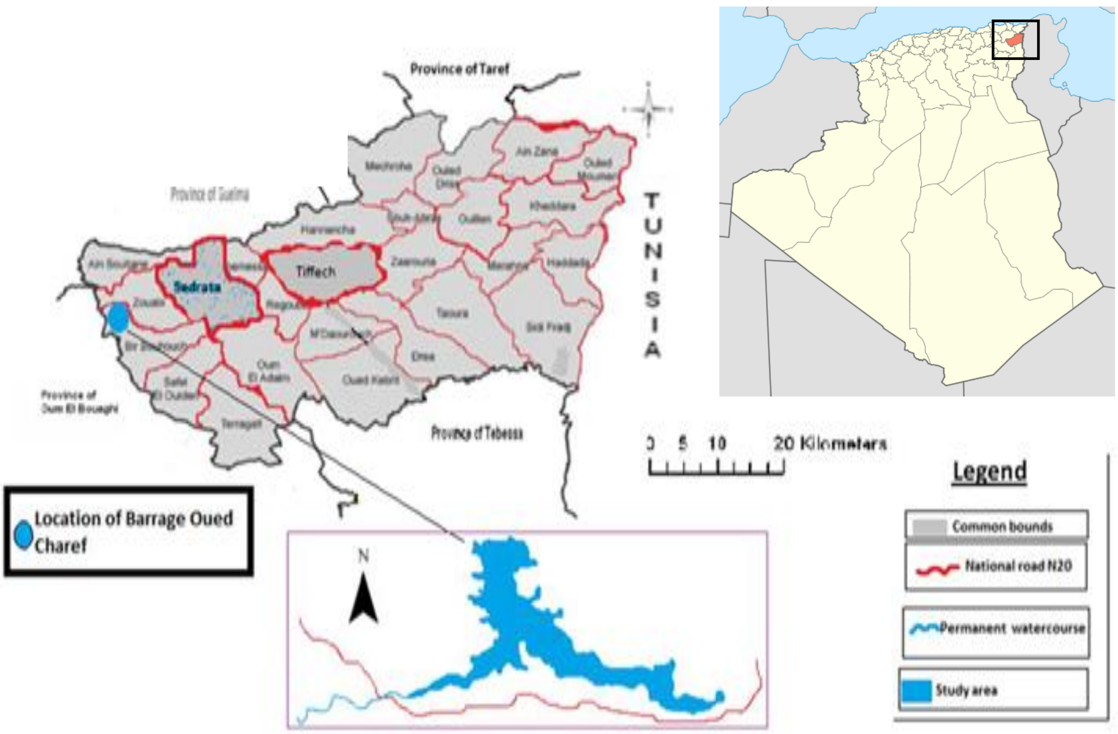

Figure 1. Map showing the location of Oued Charef dam, northeast of Algeria (Established by Boukrouma 2018)

Data analysis

The *R* 4.0.3 software was used for data analysis to calculate arithmetic average, standard deviation, minimum and maximum value for each of the studied features, for each species, and edaphic factors.

To investigate the relationship between the vegetations and environmental factors Ward's Hierarchical Agglomerative clustering techniques (McCune Grace 2002) were used. The importance values index of vegetation was used, as it provides the degree of dominance and abundance of given species in relation to other species in the area. (Kent and Coker 1992; Song et al. 2009). To categorize the vegetation into groups the importance value of species and frequency of understory vegetation was taken.

The classification was performed in the "Facto Miner" package for a program *R* 4.0.3 (R core Team 2016). After classification of the vegetation, relationships between environmental factors (soil variables) and vegetation were studied using PCA methods. PCA is an ordination technique that constructs the theoretical variable that minimizes the total residual sum of squares after fitting straight lines to species data. PCA does so by choosing the best values for the sites (Jafari et al. 2003). Also, species with high variance, often the abundant ones, therefore dominate the PCA method, whereas species with low variance, often the rare ones, have an only minor influence on the method. These may be reasons to apply standardized PCA, in which all species receive equal weight (Jafari et al. 2003). Before analysis, the scaling was focused on inter-species correlations, samples were cantered and standardized, but the data were not transformed. The selection of environmental variables was automatic.

RESULTS AND DISCUSSION

Cluster hierarchical classification of terrestrial species

The dendrogram was prepared using Ward's Clustering Method, (Figure 2) clearly separate out the six major groups of vegetation and on the basis of these groups, environmental variables are also divided into six groups (Table 1) along with the environmental features of each (Table 2).

Group (1): This group consists of 34 stands (Figure 2). In this group, the dominant species was *Daisies chrysanthemum* (Table 1). The edaphic feature showed mean value of Sand (FSA) 0.66±0.01, Silt (FSI) 57.17±0.52, clay 0.85±0.01, C/N 14.44±0.01, salinity (mg/l) 38.8±0.42 and conductivity (us/cm) 82.6±0.53. The soil of this group was alkaline having the man value of pH 7.49 ±0.31. The soil nutrients this group showed the value of nitrates (NO_3) 560±0.03, nitrites (NO_2) 1.8 ± 0.04, TN (nitrogen) 300 ±0.42, and phosphorus 14.44±0.02 (mg/kg) respectively (Table 2).

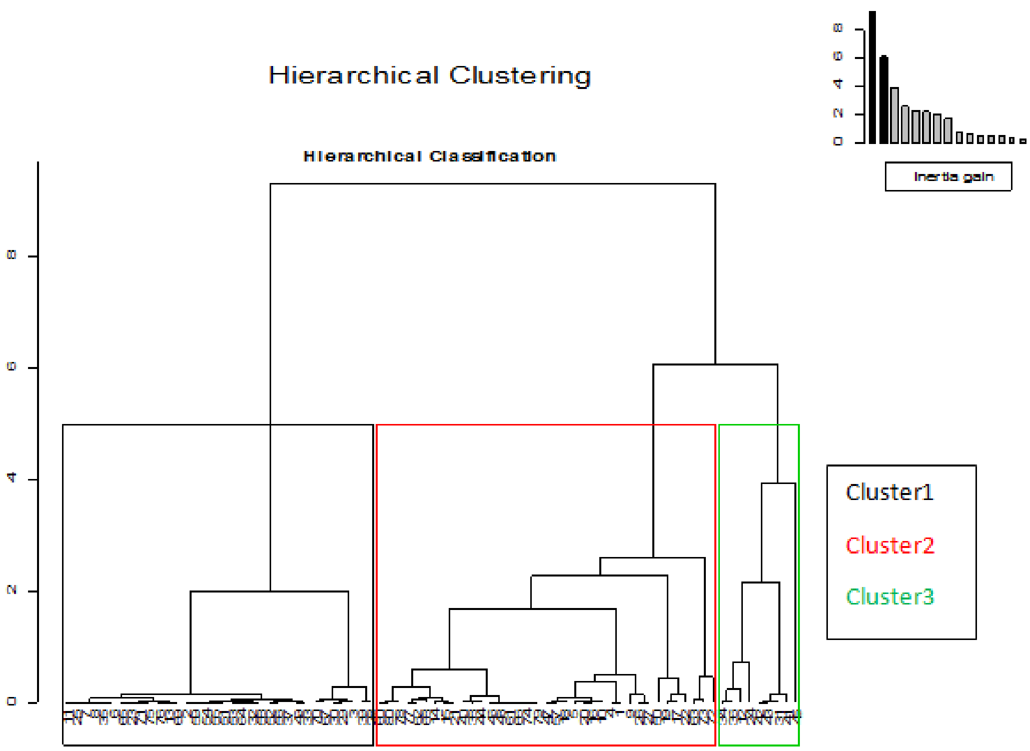

Figure 2. Dendrogram obtained from Ward's Cluster Analysis, using importance value of terrestrial species, showing three distinct groups, Oued Charef dam, northeasten of Algeria

Group (2): This is the largest group compared to the other cluster groups predominantly by *Cynodon dactylon L* with 100 % average frequency. (Table 1). The Edaphic feature of this group showed mean value of Sand (FSA) 3.24±0.01, Silt (FSI) 69.82±0.52, clay 2.69±0.01, C/N 4.65±0.01, salinity (mg/l) 65.4±0.42 and conductivity (us/cm) 81.1±0.53. The soil of this group was alkaline having the man value of pH 9.04 ±0.53. While in case of the soil nutrients this group showed the value of nitrates (NO_3) 270±0.03, nitrites (NO_2) 6.9 ± 0.04, TN (nitrogen) 166 ±0.01, and phosphorus 15.69±0.02 (mg/kg) respectively (Table 2).

Group (3): The dominant species in this group is *Fumana thymifolia* with average frequency of 95%. The Edaphic feature of this group showed mean value of Sand (FSA) 4.59±0.01, Silt (FSI) 78.22±0.52, clay 1.37±0.01, C/N 6.9±0.01, salinity (mg/l) 85.3±0.42 and conductivity (us/cm) 138.7±0.53. The soil of this group was neutral having the man value of pH 7.49 ±0.53. While in case of the soil nutrients this group showed the value of nitrates (NO_3) 390±0.03, nitrites (NO_2) 4.4 ± 0.04, TN (nitrogen) 133 ±0.01, and phosphorus 26.48±0.02 (mg/kg) respectively (Table 2).

To determine most effective variables on the separation of vegetation types, PCA was performed on 11 factors in 50 sample plots (Figure 3). The first ordination axis (PC1, 42.1%) showed a positive correlation with nitrates (NO_3) phosphorus (PO_4), FSA, FSI, TN, clay, and a negative correlation with pH, conductivity (EC), salinity, C/N. Defined by the appearance of species: *A.mil, A.mre, A.syl, A.mic, B.spi, C.tet, C.cor, CA. vul, C.sol, C.und, C.ari, F.com, G.pus, M.par, M.vul, O.mac, P.arg, P.arg, P.aus, P.cor, R.alb, R.bul, S.hys, S.acr, S.cae, S.ale, S.med, T.nit, U.mar, S.pass, Ci.vul, S.pass, V.tha* (Figure 3). In addition, the second component (PC2, 28.5%) is characterized by a positive correlation with conductivity (EC), salinity, nitrates (NO_3), nitrites (NO_2), TN and negative with pH, C/N, CS, FSA favoring the appearance of species; *A.her, S.leu, E.vul, G.aly, H.spi, A.ber, E.sph, J.sco, C.arv, J.occ, T.gal, E.inc, H.rad, L.ang, D.chy, F.thy* (Figure 3).

Table 1. Average frequency of understory terrestrial species in the three groups derived from Ward's cluster analysis of the terrestrial vegetation data, Oued Charef dam, North East of Algeria

Species	Code	Group 1	Group 2	Group 3
Achillea maritima	*A.mar*	60	55	52
Achillea millefolium	*A.mil*	14	14	0
Agrito berberis trifoliolata	*A.ber*	20	11	60
Ammophila arenaria	*A.are*	50	50	50
Ampelodesma mauritanica	*A.mre*	60	50	18
Anthriscus sylvestris	*A.syl*	10	9	0
Artemisia herba-alba	*A.her*	4	2	8
Asphodelus microcarpus	*A.mic*	12	2	0
Astragalus monspessulanus	*A.mon*	68	66	30
Atriplex halimus	*A.hal*	60	60	20
Belechnum spicant	*B.spi*	4	0	0
Calendula arvensis	*C.arv*	43	40	90
Californica tetragoniatetra	*C.tet*	20	10	10
Canadian horseweed	*C.hor*	60	56	0
Capsella bursa-pastoris	*C.bur*	60	45	8
Carlina corymbosa	*C.cor*	77	70	0
Carlina vulgaris	*C.vul*	70	68	40
Centaurea solstitialis	*C.sol*	79	71	4
Cirsium undulatum	*C.und*	70	66	33
Cirsium vulgare	*C.vul*	70	68	10
Coronilla varia	*C.var*	58	47	2
Crepis bursifolia	*C.bur*	66	68	43
Cupressus arizonica	*C.ari*	15	12	0
Daisies chrysanthemum	*D.chy*	100	95	82
Daucus carota	*D.car*	1	1	0
Diplotaxis erucoides	*D.eru*	80	72	20
Diplotaxis tenuifolia	*D.ten*	80	72	20
Echinops sphaerocephalus	*E.sph*	10	10	92
Echium asperriumum	*E.asp*	0	0	45
Echium vulgare	*E.vul*	10	0	45
Erucastrum incanum	*E.inc*	68	58	23
Eryngium bourgatii	*E.bou*	22	12	0
Eryngium campestre	*E.cam*	30	30	0
Erysium scoparium	*E.sco*	60	60	80
Ferula communis	*F.com*	10	8	0
Fumana thymifolia	*F.thy*	70	66	95
Geranium pusillum	*G.pus*	22	25	5
Glaucium flavum	*G.fla*	44	36	3
Globularia alypum	*G.aly*	0	0	80
Hedysarum spinosissimum	*H.spi*	30	25	0
Hypochaeris radicata	*H.rad*	90	92	0
Juniperus occidentalis	*J.occ*	16	16	8
Juniperus scopulorum	*J.sco*	13	11	8
Carthamus lanatus	*C.lan*	40	33	6
Cynodon dactylon	*C.dac*	95	100	93
Lagus ovatus	*L.ova*	80	50	60
Eryngium campestre	*E.cam*	30	20	25
Lavandula angustifolia	*L.ang*	22	20	0
Malva parviflora	*M.par*	60	62	0
Marrubium vulgare	*M.vul*	20	12	28
Matthiola incana	*M.inc*	19	20	2
Onopordum macracanthum	*O.mac*	30	22	0
Papaver rhoeas	*P.rho*	12	10	0
paronychia argentea	*P.arg*	20	18	0
Paronychia argentea	*P.arg*	20	18	0
Phragmite australis	*P.aus*	32	28	0
Plantago coronopus	*P.cor*	58	50	2
Raphanus raphanistrum	*R.rap*	12	20	0
Reseda alba	*R.alb*	18	16	0
Romulea bulbocodium	*R.bul*	28	5	0
scilla peruviana	*S.per*	25	23	18
Scolymus hyspanicus	*S.hys*	55	40	2
Scornozera humilis	*S.hum*	60	40	0
Sedum acre	*S.acr*	18	12	0
Sedum caeruleum	*S.cae*	10	9	0
Sedum sediforme	*S.sed*	25	41	45
Senecio leucanthemifolius	*S.leu*	0	0	40
Sonchus asper	*S.asp*	50	52	20
Sonchus oleraceus	*S.ale*	22	16	12
Fallugia paradoxa	*F.par*	23	25	26
Stellaria media	*S.med*	18	12	0
Stoebe passerinoides	*S.pass*	28	20	0
Tamarix gallica	*T.gal*	27	28	0
Thunberg meadowsweet	*T.mea*	25	24	63
Thymelea nitida	*T.nit*	19	18	4
Thymus algeriensis	*T.alg*	8	10	8
Urginea maritima	*U.mar*	45	48	0
Verbascum thapsus	*V.tha*	30	30	0
Eriogonum latifolium	*E.lat*	25	63	47
Xanthium strumarium	*X.str*	22	11	0

Table 2. Mean values and standard error (±SE) values of the soil variables in the vegetation groups (1-3) obtained by TWINSPAN classification in Oued Charef dam, North East of Algeria

Soil variables	Mean	Vegetation groups		
		1	2	3
Sand (FSA) %	2.83±0.01	0.66±0.01	3.24±0.01	4.59±0.01
Silt (FSI) %	74.40±0.52	75.17±0.52	69.82±0.52	78.22±0.52
Clay %	1.63±0.01	0.85±0.01	2.69±0.01	1.37±0.01
Salinity mg/l	63.16±0.42	38.8±0.42	65.4±0.42	85.3±0.42
Conductivity (EC) us/cm	100.8±0.53	82.6±0.53	81.1 ±0.53	138.7±0.53
pH	8,66 ±0.53	7,49 ±0.31	9,04 ±0.31	7,49 ±0.31
Nitrates (NO_3) mg/kg	390±0.03	560±0.03	270±0.03	390±0.03
Nitrites (NO_2) mg/kg	4.36 ± 0.04	1.8±0.04	6.9±0.04	4.4±0.04
TN (nitrogen) mg/kg	199± 0.42	300± 0.42	166± 0.42	133± 0.42
Phosphorus mg/kg	18.87±0.02	14.44 ±0.02	15.69 ±0.02	26.48±0.02
C/N %	4.22 ±0.01	1.12±0.01	4.65±0.01	6.9±0.01

Note: SE: Standard error, EC: Electrical conductivity

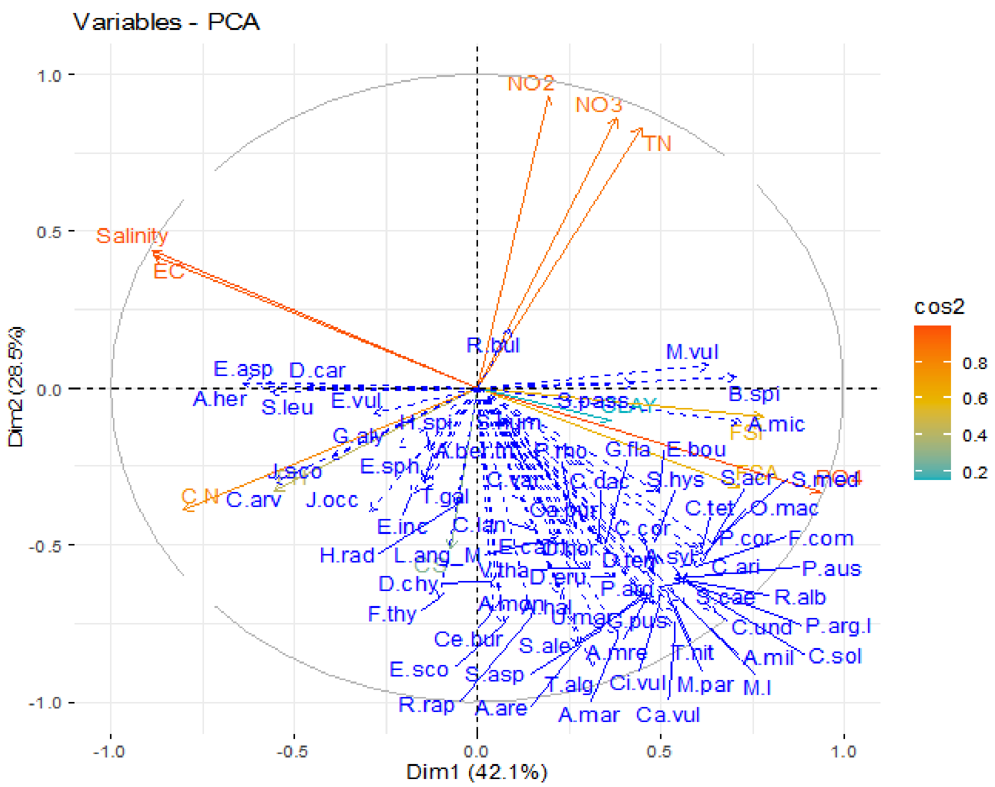

Figure 3. A plot of terrestrial species against their values for axes 1 and 2, Oued Charef dam, northeastern of Algeria

Discussion

Environmental factors indeed hierarchically play a key role in distribution and composition of association. Lovtt et al. (2001) and Gajoti et al. (2010) described that the environmental variables contribute very important role in classification of species groups. By Ward's cluster analysis, species groups were recognized as vegetation data domination with various plant species. In the present study, the application of PCA ordination indicated that the most effective soil variables correlated with the presence and distribution of the species elements in the vegetation of Oued Charef dam are: conductivity (EC), FSA, FSI, clay, salinity, phosphorus (PO_4), TN (nitrogen), nitrates (NO_3) and nitrites (NO_2). Similar results were found in lowlands, temperate forests, arid grasslands, beech forests, and natural forests (Peres-Neto et al. 2006, Dwirek et al. 2006). Plant communities are affected by many factors as farm management practices (Andersson and Milberg 1998), crop species (Andreasen and Skovgaard 2009), season (El-Demerdash et al. 1997), and soil characteristics (Pinke et al. 2010).

One of the effective variables in the separation of species in the study is conductivity. Similarly, Monier et al. (2006), who categorized 25 plant populations using soil properties, found that conductivity was one of the most important factors. Shaltout et al. (2002) concluded that conductivity was a key factor in species community separation. Conductivity contains rich information about physical properties and soil quality, which is crucial for plant growth (Jager et al. 2015).

Adel et al. (2014) identified soil texture (clay, FSA, FSI) as the main factors affecting the distribution of plant communities in northern Iran. These results agree with our findings. Also, Badano (2005) reported role of clay, as a key factor in the distribution of plant species in Mediterranean matorral of central Chile. Other researchers such as Zarei (2010) and Naseri (2009) proved that soil texture (proportions of clay, silt (FSI) and sand (FSA)) are one of the most important factors in determining plant distribution. Ismaelzade et al. (2011) associated the amount of sand with developing different types of plant forests. The proportions of clay and sand in soil are drivers of vegetation distribution, because sandy soils have lower water retention capacity and cation exchange capability (Larcher 1995). Some species can become more competitively aggressive with more nutrients adsorbed in high organic matter and clay soils.

Salinity was one of the most important soil factors determining the occurrence of terrestrial species group in this study. These results agree with the findings of Shaltout et al. (2002).

Phosphorus and nitrogen (TN) were one of the important soil factors in the separation of the ecological groups in Oued Charef dam. These findings agree with Biggelow and Canham (2002) who documented positive association of Phosphorus and nitrogen content with plant species in northeastern America. Amorin & Batalha (2007) reported that phosphorus was the main factor that defined plant communities in Brazil, and nutrients, in general, played a major role in the classification of ecological groups. Nitrogen is a key nutrient in many biological processes and itis the main factor in plant growth. It also has a major influence on soil fauna and flora that can either make nutrients more available to plants or bind them in biological processes and growth causing short-term deficiencies in plants (Abella and Covington 2006; Jiang et al. 2012). Phosphorus is a key element in cellular energy transfer and a structural element in nucleic acids. Nitrogen and Phosphorus are also the primary nutrients that restrict plant growth in many natural environments (Jiang et al. 2012). High soil nitrogen content might promote resprouting vigor in many species (Di Tommaso and Aarsen 1989; Wilson and Tilman 1993), predicting that more re-sprouters will be found in soil patches with high nitrogen content. The presence of nitrogen changes the relationship between plants and soil resources (Hector and Loreau 2005).

Our results showed that the presence of species plants is related to nitrates and nitrites. These results are similar to the report by Su et al. (2002) and Zhenghu et al. (2004) in the Tengger Desert of China. Nitrates and nitrites are the key nutrients in many biological processes and there is the main factor in plant growth. They also have a major influence on soil fauna and flora that can either make nutrients more available to plants or bind them in biological processes and growth causing short-term deficiencies in plants. (Fu et al. 2004).

Our results showed that pH factor does not play an important role in the vegetation community succession process. Jobbagy and Jackson (2003) have reported that soil pH is an important determinant of the productive capability of plant species. Kashina et al. (2003), Gough et al. (2000), and Brofske et al. (2001) demonstrated the important role of pH in the separation of plant groups. This finding degree with our results.

This difference could be explained by a specific limitation threshold for some soil resources. So, wetland management must work with vegetation communities by taking into account all of the interrelated biotic and abiotic influences. Understanding the relationships between environmental variables and vegetation distribution can improve the management, reclamation, and development of wetland ecosystems.

In conclusion, the ability to identify ecological species groups and understand the environmental relationships that underlie their occurrence in this wetland can be used to evaluate site conditions, assess the quality of current vegetation, identify priority sites for restoration and determine appropriate species for specific sites. This study showed relationship between variation in soil characteristics and plant populations in Oued Charef dam. However, due to its large surface and small number of plots, this study has not completely described the species plant of the wetland. Further studies with more sample plots located by considering the surface of habitat will give a more comprehensive description of the relationship between soil characteristics and plant populations in Oued Charef wetland.

More studies can be conducted to add ecological understandings and help biodiversity conservation. For example, other environmental factors including atmosphere, water level, climate, rainfall, or others should be studied to better understand the effect's environmental factors on plant biodiversity. Another topic is the study of relationships of plant biodiversity with productivity and soil fertility in different ecosystems. Currently, the study area as a strict nature reserve has been drastically changed by human induce and other natural disturbances, and therefore should be restored.

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