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Ecological Relationships between Vegetation and Environmental Related Variables inTiffech Lakewetland, North Est of Algeria

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Abstract The purpose of this study is to define the relationship between vegetation and environmental variables from Tiffech Lakewetland,North Est of Algeria. Ward's cluster analysis for classification and principal component analysis (PCA) for ordination were applied to estimate vegetation distribution and composition. Classification indicated comparabledistribution pattern of species as well as understory vegetation.The hierarchical classification of aquatic species showed that three groups were distinct. *Ranunculus peltatus* was the indicator species for Group 1 and 2, and *Acorus calamus* was the dominate species of Group 3. Aquatic plant species and water factors in the PCA analysis indicatedthat *Scirpus lacustris*, *Scirpus maritimus* and *Phragmites australis* were mainly affected by dissolved oxygen, nitrites, phosphorus and ammonium, whereas *Acorus calamus* and *Ranunculus peltatus*by water total phosphorus. Six ecological groups from terrestrial species were specified in the studyarea.The most important environmental factors associated with plant composition in Tiffech Lake communities were phosphorus, magnesium, potassium, sodium, nitrogen, organic matter and C/N ration. The use of natural vegetation as an indicator for site quality provides good results, due to the close relationship it has with abiotic site characteristics.

Keywords PCA,Environmental variables,Cluster hierarchical classification, Tiffech Lakewetland.

Introduction

Species-environment relationships are one of the main tasks of plant ecologists. In ecological studies, vegetation composition data has commonly been used to detect relationships between environmental variables and plant species combinations and to identify ecological species groups (White and Hood 2004). Ecological species groups are comprised of plants that repeatedly occur together when certain combinations of site factors occur; they are species that are perceived to have similar eco-logical requirements or tolerances to environmental stresses and limitations. Ecological species groups are distinguished by their species composition and abundance patterns among sampling plots. Identifying ecological species groups involves recognizing species that share similar environmental affinities and typically occupy the same sites across the landscape in predictable relative proportions (Adel et al2014) and can be used to indicate environmental complexes of wetlands based on the presence and abundance of these different indicator species that form associations with fidelity to site (Cornwell et al 2009). The ecological species groups help to distinguish and map landscape ecosystems in the field by their presence or absence. Many factors typically influence on plant wetland communities. Among these, elevation, disturbance, and soil properties are prominent in the literature (Welch et al 2006).However, the existing studies yield mixed results, from which no generalization emerges. The greater influence of soil properties such as soil moisture, salt content (Rath and Rousk 2015), soil organic matter (Bahrami et al2017), nitrate (Green and Galatowitsch 2002) and soil microbial communities (Qin 2017) is documented.However, Lovtt et al(2001) and Gatti et al(2014) observed that more than soil properties, geographical attributes are more influential.In Algeria, limitedstudy relating ecological species groups to environmental variables was done by Bezzalla et al(2018) . However, ecological impact and biotic interactions and/or spatial and temporal plant distribution still remains poorly understoodin the Algeria wetlands. The present study aims to identify the main ecological species groups in Tiffech Lake wetland as a pristine pilot study site in the north-east of Algeria, based on TWINSPAN classification, and to evaluate the relationships between environmental factors (water and soil variables) and ecological species groups using multivariate analyses (PCA). This study also evaluates how environmental factors affect the distribution of the ecological species groups.

Materials and methods

Site description: This study was carried out in Tiffech Lake, wetland,north-east of Algeria (36°08.513 N, 07°45.417E)(Fig.1)**.**The area is approximately 110 ha, elevation ranging from 824 to 868m a.s.l. The annual precipitation varies in the range 129–496 mm with more than 70% concentrated in winter. The minimum recorded temperature was 4.52°C in December and the maximum recorded temperature was 30.93°C that occurred in July (Boukrouma et al 2018).

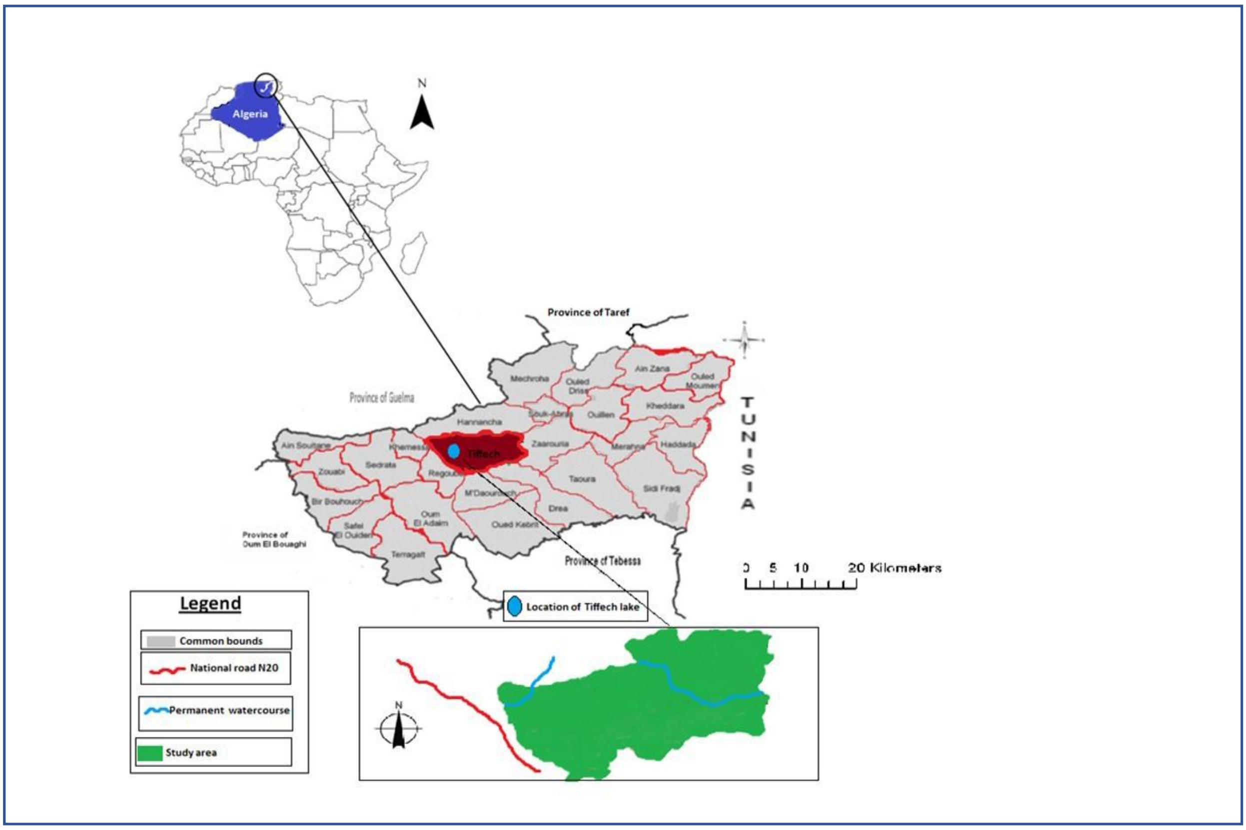

Fig 1. Study area

Data collection: To include a range of different environmental conditions, the samples were selected based on a land unit map. The areaof plots in each plant types was determined by the mini-mum surface method using a nested plot technique andarea/species curves (Mueller-Dombois and Ellenberg1974).The 47 homogenous plotswere placed systematically to determine plant distribution and diversity. The vegetation of research plots was surveyed according to the standard central European method (Braun-Blanquet 1964). Cover estimates were made for the tree, shrub , herb and moss layer. The source of the nomenclature were Martincic et al(1999) for vascular plants , Coreley et al (1981), and Corely and Crundwell(1991) for mosses , Grolle and Long (2000) for liverworts. The source of caracterisation of the plant species according to the phytosociological units was Oberdorfer (1983, 1992).

Laboratory study:

Soil analysis: From all the 47 research plots soil samples at depths of 0-20 cm were collected.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 and conductivity were measured using a glass electrode pH meter (McLean 1982) and electric conductivity meter, respectively (Rhoades1982), organic matter by the Walkley and Black's method (Nelson and Sommers 1982) ; phosphorus by Olsen method (Olesen and Madsen 2000) ; carbonate content by using dry combustion (Iso 1994, 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). Nitrogen content was determined by the Kjeldahl Method (Bremner and Mulvaney1982).On the basis of these measurements calculated the C/N ration.

Water analysis: Sampling of the aquatic vegetation was carried out over 100 m stretches of the Lake betweenNovember 2018 to August 2019. The samples were collected from four different points and were mixed together to prepare an integrated sample. From the time of sample collection and to the time of actual analysis, many physical and chemical reactions would change the quality of water sample, therefore to minimize this change the sample were preserved soon after the collection. The water samples were preserved by adding chemical preservatives and by lowering the temperature.Temperature and oxygen were measured with a WTW OXI 197i oxygen meter with the EOT 196 electrode. Total nitrates,nitrites, phosphorus, ammonium and chlorides were estimated with a MERCK Spectroquant cuvette test on the UV-VIS spectrophotometer.

Data analysis: The *SPSS*(version 18.0)software was used for data analysis.To investigate the relationship between the vegetations and environmental factors Ward's Hierarchical Agglomerative clustering techniques (McCune and Grace 2002) was used. The importance values index of vegetationwas 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. A classification was performed using a program, *SPSS*(version 18.0). After classification of the vegetation, relationships between environmental factors (water and soil) and vegetation were studied using PCA methods.The, species with high variance, often the abundant ones, therefore dominate the PCAmethod, whereas species with low variance,often the rare ones, have only minor influenceon the method.

Results and discussion

Cluster hierarchical classification of terrestrial species

The dendrogram was prepared using Ward's Clustering Method, (Fig. 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).

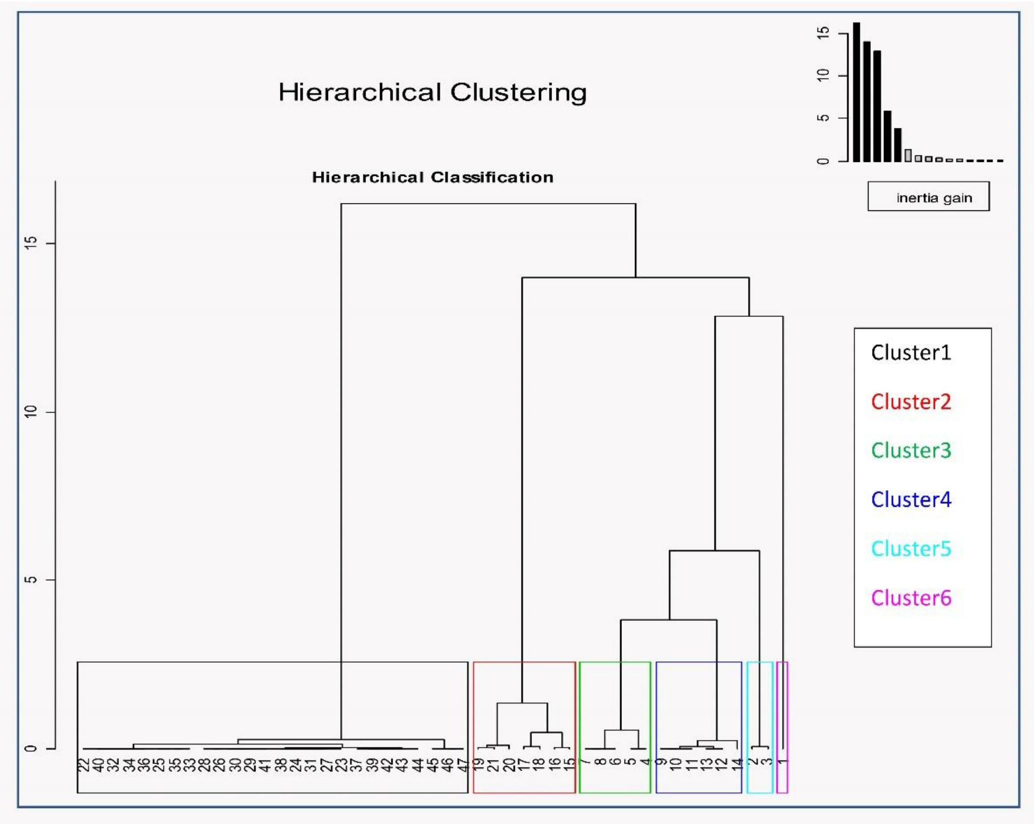

Fig. 2. Dendrogram obtained from Ward's Cluster Analysis, using importance value of terrestrial species, showing six distinct groups.

Group (1):

Erigeron Canadensis*:* This is a largest group as compared to the other cluster groups which comprises of 26 stands was predominantly *Erigeron canadensis, Erigeron sumatrensisand Galactites tomentosus*with 76.92% average frequency. (Table 1).

Table1. Average frequency of understory terrestrial species in the six groups derived from Ward's cluster analysis of the terrestrial vegetation data.

Group number		1	2	3	4	5	6
Species	Code						
Anthriscus sylvestris	*(A.syl)*	0	0	100	0	100	100
Daucus carota	*(D.car)*	0	0	100	0	100	100
Allium ampeloprasum	*(A.amp)*	0	0	100	0	100	100
Allium schoenoprasum	*(A.sch)*	0	0	100	0	100	100
Muscari neglectum	*(M.neg)*	0	0	100	0	100	100
Bombycilaena erecta	*(B.ere)*	0	0	0	0	0	0
Calendula arvensis	*(C.arv)*	0	0	0	0	0	0
Calendula officinalis	*(C.off)*	0	0	0	0	0	0
Chamaemeluum nobile	*(C.nob)*	0	14.28	0	100	0	0
Carduus acanthoides	*(C.aca)*	0	14.28	0	100	0	0
Carduus nutans	*(C.nut)*	0	14.28	0	100	0	0
Carduus pycnocephalus	*(C.pyc)*	0	14.28	0	100	0	0
Cirsium vulgare	*(C.vul)*	0	14.28	0	100	0	0
Crepis capillaris	*(C.cap)*	0	14.28	0	100	0	0
Cynara humilis	*(C.hum)*	38.46	85.71	0	0	0	0
Cynara scolymus	*(C.sco)*	38.46	85.71	0	0	0	0
Dittrichia viscosa	*(D.vis)*	38.46	85.71	0	0	0	0
Echinops sphaerocephalus	*(E.sph)*	38.46	85.71	0	0	0	0
Erigeron canadensis	*(E.can)*	76.92	85.71	0	0	0	0
Erigeron sumatrensis	*(E.sum)*	76.92	85.71	0	0	0	0
Galactites tomentosus	*(G.tom)*	76.92	85.71	0	0	0	0
Hyoseris radiata	*(H.rad)*	61.53	0	0	0	0	0
Micropus supinus	*(M.sup)*	57.69	0	0	0	0	0
Pallenis spinosa	*(P.spi)*	57.69	0	0	0	0	0
Silybum marianum	*(S.mar)*	57.69	0	0	0	0	0
Senecio vulgaris	*(S.vul)*	57. 69	0	0	0	0	0
Sonchus asper	*(S.asp)*	61.53	0	0	0	0	0
Sonchus oleraceus	*(S.ole)*	61.53	0	0	0	0	0

Contd..

Sonchus terrimus	*(S.ter)*	61.53	0	0	0	0	0
Urospermum dalechampii	*(U.dal)*	61.53	0	0	0	0	0
Anchusa officinalis	*(A.off)*	61.53	0	0	0	0	0
Borago officinalis	*(B.off)*	61.53	0	0	0	0	0
Cynoglossum creticum	*(C.cre)*	61.53	0	0	0	0	0
Echium asperrimum	*(E.asp)*	61.53	0	0	0	0	0
Lithodora fruticosa	*(L.fru)*	61.53	0	0	0	0	0
Alyssum alyssoides	*(A.aly)*	61.53	0	0	0	0	0
Eruca vesicaria	*(E.ves)*	61.53	0	0	0	0	0
Lepidium draba	*(L.dra)*	61.53	0	0	0	0	0
Sinapis arvensis	*(S.arv)*	61.53	0	0	0	0	0
Capsella bursa-pastoris	*(C.bur)*	61.53	0	0	0	0	0
Reseda alba	*(R.alb)*	61.53	0	0	0	0	0
Beta vulgaris	*(B.vul)*	61.53	0	0	0	0	0
Paronychia argentea	*(P.arg)*	61.53	0	0	0	0	0
Stellaria media	*(S.med)*	38.46	0	0	0	0	0
Rumex crispus	*(R.cri)*	38.46	0	0	0	0	0
Tamarix gallica	*(T.gal)*	38.46	0	0	0	0	0
Ampelodesmos mauritanicus	*(A.mau)*	38.46	0	0	0	0	0

The edaphic feature showed mean value of conductivity 0.15, C/N 6.43and organic matter 5.5. The soil of this group was neutralin nature having the man value of pH 7.8.The soil nutrients this group showed the valueof phosphorus 0.02,carbonate potassium 6.03, p0.3, magnesium 1.76, calcium 39.73and sodium 0.04(c mol(+)/mg) respectively (Table 2).

Group (2): This group consists of seven stands having13 species (Table 1).In this group no species was occurring in frequent, abundant and very abundant category. The results indicated that most of the species were getting pressure due to the natural and human induced disturbances therefore most of the species distributed rarely. The

Table 2. Environmental variables (edaphic and Soil nutrient) based on six groups derived from Ward's cluster analysis using vegetation data of 47 stands (Mean values ± SE)

Variable	Groupe 1	Groupe 2	Groupe 3	Groupe 4	Groupe 5	Groupe 6
Edaphic variables						
pH	7.8±0.1	8.07±0.2	7.89±0.6	7.91±0.1	7.87±0.1	7.01±0.4
Conductivity [µS cm^{-1}]	0.15±0.1	0.19±0.1	0.24±0.1	0.20±0.1	0.21±0.1	0.25±0.1
C/N (%)	6.43±0.1	6.4±0.1	6.52±0.1	6.42±0.1	6.45±0.1	6.53±0.1
Organic matter (%)	5.5±0.6	5.5±0.6	5.5±0.6	5.5±0.6	5.5±0.6	5.5±0.6
Soil nutriments						
Phosphorus (c mol(+)/mg)	0.02±0.6	0.03±0.6	0.04±0.6	0.04±0.6	0.02±0.6	0.01±0.6
Carbonate (c mol(+)/mg)	6.03±0.8	5.31±0.7	13.03±0.6	13.63±1.3	6.21±0.4	6.02±0.6
Potassium(c mol(+)/mg)	0.3±0.1	1.1±0.1	1.76±0.1	1.2±0.1	0.46±0.1	0.45±0.1
Magnesium (c mol(+)/mg)	1.76±0.1	2.83±0.1	2.02±0.1	2.4±0.1	1.6±0.1	1.8±0.1
Calcium (c mol(+)/mg)	39.73±6.1	43.13±7.8	40.03±9.5	42.8±8.2	38.5±7.4	43.05±0.1
Sodium (c mol(+)/mg)	0.04±0.1	0.33±0.1	0.76±0.1	0.43±0.1	0.76±0.1	0.42±0.1

SE = Standard error, (Mean ±SE).

Edaphic feature of this group showed mean value of conductivity 0.19, C/N 6.40and organic matter 5.5 . The soil of this group was neutralin nature having the man value of pH 8.07. while in case of the soil nutrients this group showed the mean value of 0.03 phosphorus, carbonate potassium5.31, p 1.76, magnesium 2.02, calcium 43.13and sodium 0.33 (c mol(+)/mg) respectively (Table 2).

Group (3), (5) (6): This is a smallest group as compare to the earlier groups. In this groups the ground flora comprises of five species (Table 1).

Group (4): The indicator species were: *Chamaemeluum nobile, Carduus acanthoides,Carduus nutans, Carduus pycnocephalus,Cirsium vulgare and Crepis capillaris*.(Table 1).

The Edaphic feature of this group showed mean value of conductivity 0.20, C/N 6.42and organic matter 5.5 . The soil of this group was neutralin nature having the man value of pH 7.91. The soil nutrients this group showed the value of 0.04 phosphorus, carbonate potassium 13.63, p 1.2, magnesium 2.4, calcium 42.8 and sodium 0.43 (c mol(+)/mg) respectively (Table 2).

The first ordination axis (PC1,60.52%) showed a positive correlation with phosphorus, magnesiumand a negative correlation with carbonate.Defined by the appearance of species: *E .hel, A.fat, D.glo ,H.mur, P.lan, P.afr, S.ver, D.car, B.ere, C.arv ,C.off, C.nob,C.ana, C.pyc, C.vul, C.cap, C.hum, C.Sco, D.vis, E.sph E.can , E.sun, C.tom, H.rad, M.sup ,S.mar S.vul , S.asp, S.ole, S.ter, U.dal, A.off, B.off, C.cre, E.asp, L.fru, E.ves, L.dra, S.arf, R.cri, S.med, R.albv, A.cha, M.min, H.alb. M.meg, L.car, L.balp, G.pus, C.nut. T.ste, O vul et R.off,* (Fig.3).In addition, the second component (PC2, 22.57 %) is characterized by a positive correlation with sodium, C/N, potassium, nitrogen and organic meter and negative with pHfavoring the appearance of species :*Anthriscus Sylvestris (A.syl)* and*Pallenis spinosa*(*P.spi*).(Fig. 3).

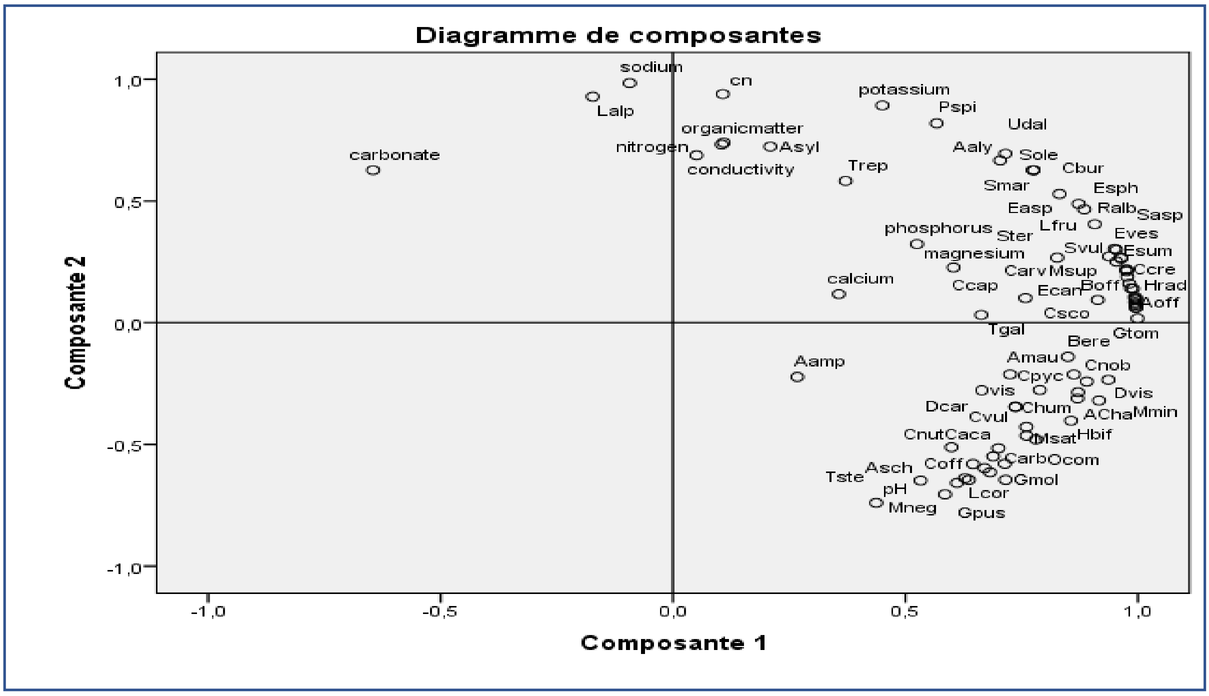

Fig. 3 . Terrestrial species against their values for axes 1 and 2.

Cluster hierarchical classification of aquatic species

The results of cluster hierarchical classification of aquatic speciesindicated three distinct groups.The water characteristics of each groups were analyzed(Table 3) .The first group, as indicated by *Ranunculus peltatus*, was included station 3 and 4 (Fig. 4). The second group consisted of station 1 which *Ranunculus peltatus* was the indicator species. *Acorus calamus*was the indicator species of the third group that was represented by station2.

Table 3. Chemical parameters of water for All the station in Tiffech Lake

Variable	Station 1	Station 2	Station 3	Station 4
pH	7.17	7.18	7.15	7.17
Temperature (C°)	17.3	18.1	18.2	18.3
Disolved oxygen [%]	6.6	6.5	6.8	6.8
Nitrites [mg dm^{-3}]	0.5	0.1	0.4	0.4
Nitrates [mg dm^{-3}]	13.2	13.1	13.5	13.5
Phosphorus [mg dm^{-3}]	0.01	0.02	0.03	0.02
Ammonium [mg dm^{-3}]	0.05	0.05	0.06	0.06
Chlorides [mg dm^{-3}]	580	547	581	520

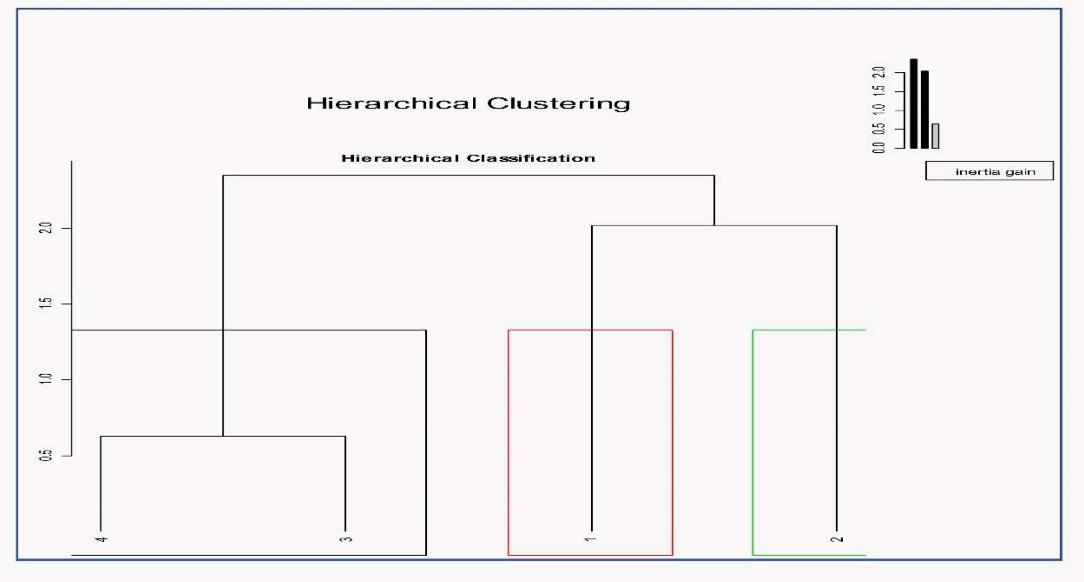

Fig. 4. Dendrogram obtained from Ward's Cluster Analysis, using importance value of aquatic species, showing three distinct groups.

To determine most effective variables on the separation of vegetation aquatic types, PCA was performed on 9 factors in the four stations.PC1 accounted for 70.91% of the total variance, which is mostly related to water properties. Therefore, among all environmental factors, water characteristics such as temperature, oxygen, nitrites, phosphorous and ammoniumwere the most effective factors in the distribution of vegetation aquatic species. The first ordination axis (PC1) showed a positive correlation with temperature, nitrites, phosphorous and a negative correlation with pH, nitrates and chlorides. The second ordination axis PC2 (19.58%) was positively correlated with phosphorous.Stations (1) and (2) project on this component defined by the high rates of dissolved oxygen, nitrites, phosphorous and ammonium and with low pH, nitrate and chloride values favoring the appearance of species: *Scirpus lacustris, Scirpus maritimus* and *Phragmites australis*. In addition, the second component is characterized by a positive correlation with phosphorous favoring the appearance of *Acorus Calamus* and *Ranunculus peltatus*in stations (3) and (4). (Fig. 5).

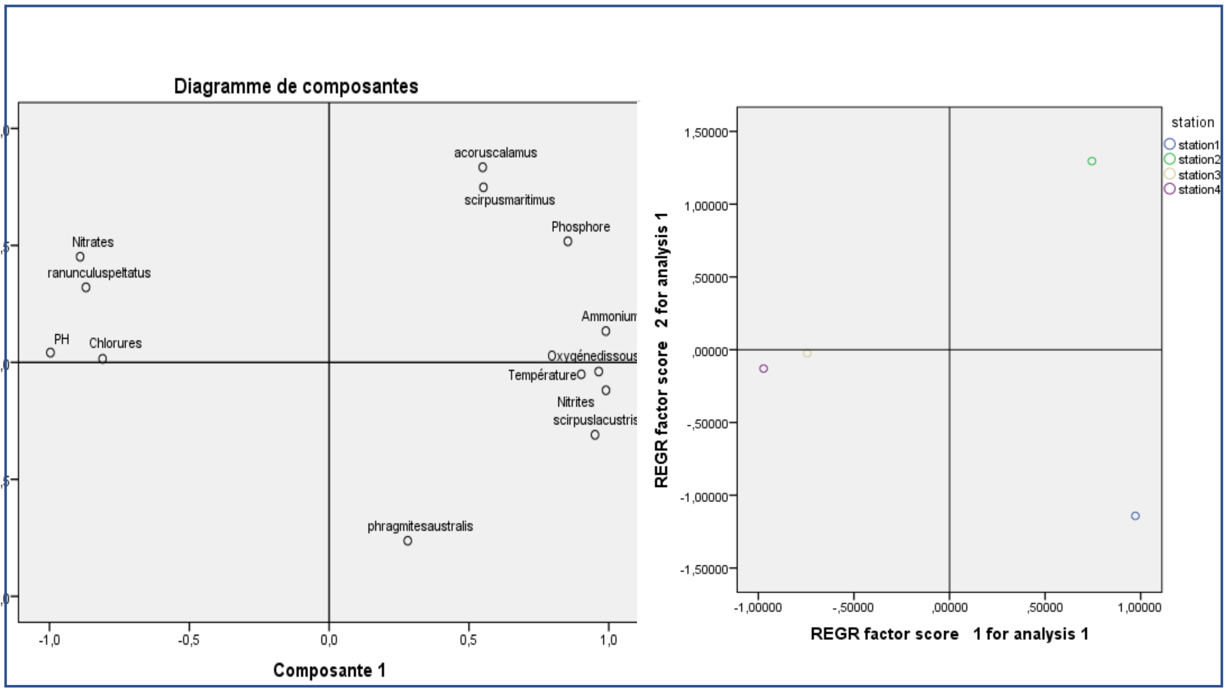

Fig. 5. AFive species against their values for axes1 and 2

Result and Discussion

This study is among the first to link vegetation distributionand environmental conditions at Tiffech lake wetland.

The plant communities in the study area were divided into six groups ofterrestrial vegetation species and three groups of aquatic species, which had substantialdifferences in their structural requirements. The ordinationanalysis showed the correlation between wetlandvegetation composition, species distribution, and factor environment.

We found that the main factors affecting terrestrial vegetation distribution wereorganic matter, nitrogen,phosphorus, potassium,magnesium and sodium.

In our study, species was found to be related to organicmatter and nitrogen.These results agree with the findings of Eshaghi et al (2010) and Naqinezhad et al (2013).Brady and Weil (1999) have reported that nitrogen and organic matter are the most important factors delimiting ecologicalspecies groups and limiting factors for plant growth.

Phosphorus was one of the most important soil factors determining the occurrence of terrestrial species group in this study. Same results have reported by Bigelow and Canham, (2002)in northeastern America and Amorim and Batalha (2007) in plant communities in Brazil. Phosphorus are important nutrients in plant metabolic processes: p is a key element in cellular energy transfer and a structural element in nucleic acids. (Jiang et al2012).

Total potassium was important in structuringCommunity of Tiffech lake. Our finding agrees with the results obtained by Lindgren and Sullivan (2001) where soil potassium affect structural diversity of plant.Zare et al (2007) and Enright et al (2005)have reported on the role of potassium in the distribution of plantspecies.Potassium plays a role in regulating photosynthesis,carbohydrate transport, protein synthesis, and other importantphysiological processes. (Gierth and Mäser 2007, Britto and Kronzucker 2008,Szczerba et al 2009).

In our study terrestrialvegetation species increased significantly with increasing soil magnesium and sodium. This finding disagrees with many studies done in other ecosystems. Fu et al (2004) and Janssens et al (1998) reported no relationship between plant species and the total magnesium and sodium. Theses studies probably had different results than us due to the different ecosystems.

Negative relationships between terrestrial species and some soil factors (carbonate and pH) could be explained by a specific limitation threshold for some soil resources.

Correlations between aquatic species and environmental factors indicated that temperature, dissolved oxygen, nitrites, phosphorous and ammoniumhad a large impact on the distribution of this species in the study area.

In our study, aquatic species was positively correlated to temperature and dissolved oxygen. Our results agree with many studies done in other study area. (Pilon and Santamaria2001 , Olesenand Madsen 2000).Temperature and dissolved oxygen influenced the distribution of aquatic plants by affecting their physiology, including the germination of seeds, initiation and rate of seasonal growth, and onset of dormancy (Rooney and Kalff 2000, Spencer et al 2000).

Our results showed that the presence of aquatic plants is related to ammonium, phosphorus and nitrites. These results are similar to the report by Heegaard et al (2001), Riis et al (2011) and Paal and Trei (2004).It has been reportedthat ammonium is an important source of nitrogen on the physiology of plants (Lachmannet al 2019).Phosphorus and nitrites are sources of plants function. (Pelton et al 1998). Fogg (1973) have reported that concentration of available phosphorus compounds controls the growth of plants in aquatic habitats.

There was a divergent relationship between aquatic species and some water variables (pH, nitrites and chlorides) in Tiffech lake . One may think that this divergent relationship was triggered by a variation in rainfall in the wetland.

Conclusion

In this paper, we analyzed the interaction between the distribution of plant communities and environmental factors (soil and water); the results also presented some relatively remarkable effects. We found that variations in soil resources are foundational and important to the distribution and abundance of plants and the communities that they form on Tiffech lake. Also, the presence of aquatic species depends on water condition in the study area. Understanding the indicator of environmental factors of a given site leads us recommend adaptable species for reclamation and improvement of that site and similar sites.

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