Asian Journal of Conservation Biology, December 2020. Vol. 9 No. 2, pp. 207-214 AJCB: FP0137
ISSN 2278-7666 ©TCRP Foundation 2020

Species diversity of plant communities associated with Environmental factors in Tiffech Lake, North East of Algeria

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(Received: November 03, 2020; Revised: November 07, 2020; Accepted: November 24, 2020)

ABSTRACT

The main objective this study was to investigate the relationship between vegetation and environmental factors (soil and water) in Tiffech Lake, North Est of Algeria. Principal component analysis (PCA) and Ward's cluster analysis were applied to determine the most effective environmental parameters controlling the distribution of vegetation type and finding the logical relationship between each plant species and environmental variables. Our results 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. Six ecological groups from terrestrial species were specified in the study area. PCA results showed that phosphorus, magnesium, potassium, sodium, nitrogen, organic matter and C/N ration were the major soil factors responsible for variations in the pattern of vegetation in Tiffech lake. 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. It is concluded that the study area needs some conservation efforts to prevent ongoing stress and degradation.

Key words: Relationship, Environmental factors, Ward's cluster analysis, Tiffech Lake, PCA.

INTRODUCTION

Wetlands ecosystems are important habitats for many species of plants at both national and international levels (Hebb *et al.,* 2013, Wetser *et al.,* 2015). Although the main causal factors of this plant diversity in wetlands is due to the diverse climatic conditions largely influenced by the nature of habitat depending upon its altitude and location in the place. (Nadeau and Sullivan, 2015). A contribution to our understanding of how a community is put together, how it works, and their spatial and temporal relationships with each other might contain something of value for describing wetlands. The vegetation in wetlands has been described by several authors who distinguished a variable number of wetland plant communities (Corriale *et al.,* 2013, Williams & Ahn, 2015); these works suggested various aspects of habitats conditions to be the main environmental factors affecting wetland plant communities, namely soil water content and soil nutrients (Jager *et al.,* 2015, Wang *et al.,* 2016). Previous studies generally focused on coastal or river wetlands; studies on freshwater lake wetland plant community composition and correlations with soil and water environmental factors were relatively infrequent.

Lake Tiffech plays an important role in north-east of Algeria in supplying water for human consumption and agricultural production. Its ecosystem has been deteriorating because of increasing levels of water pollution and eutrophication. Unfortunately, studies have rarely considered the relationships between the spatial distribution of vegetation species and environmental factors, particularly in the north-east of Algeria. Therefore, the aim of this study, was to get a better understanding of the distribution of plant communities and to investigate the main environmental factors affecting some of these communities in Tiffech lake, north-east of Algeria. This information can be further used to understand the influence of environmental factors on the wetland flora of the area as well as during the management and conservation.

MATERIALS AND METHODS

Study site

This study was carried out in Tiffech Lake, wetland, north-east of Algeria (36°08.513 N, 07°45.417E) (Figure1)**.** 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).

Data collection

To include a range of different environmental conditions, the samples were selected based on a land unit map. The area of plots in each plant types was

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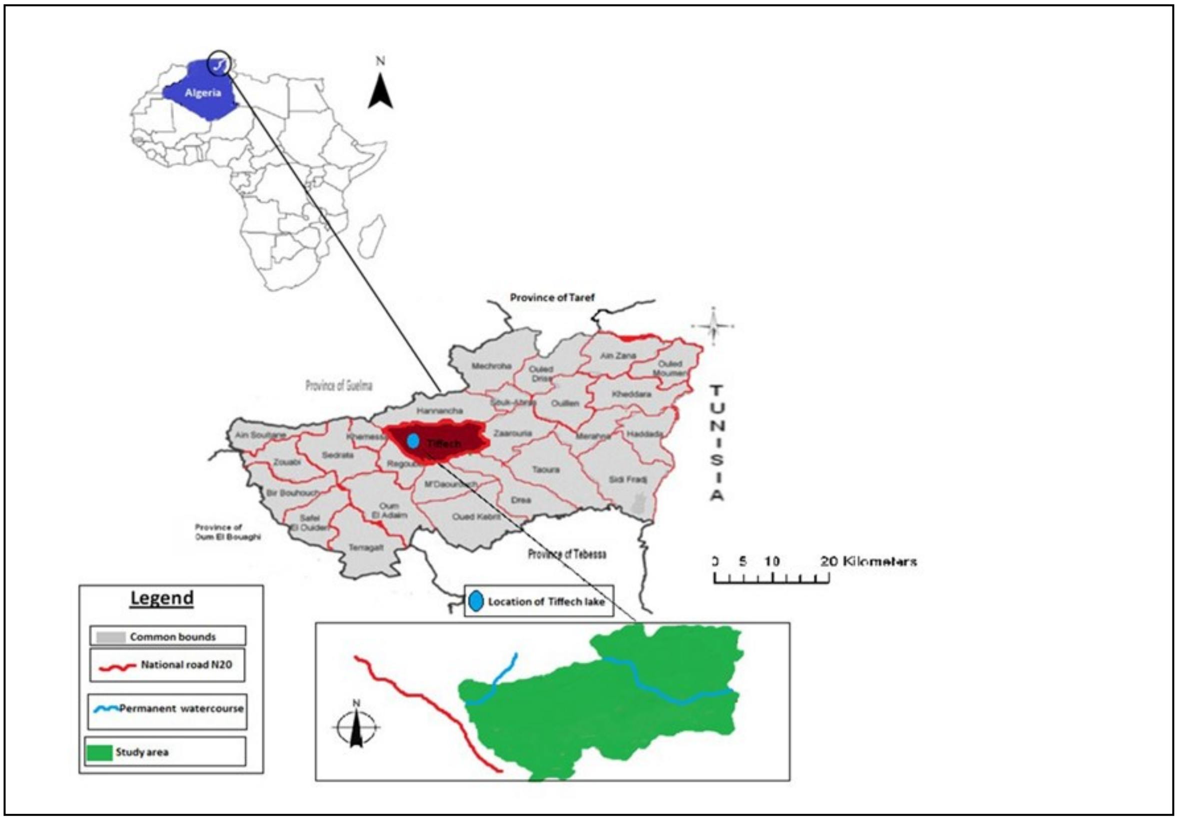

Figure 1. Map showing the location of Tiffech lake, North Est of Algeria

determined by the mini-mum surface method using a nested plot technique and area/species curves (Mueller-Dombois & Ellenberg, 1974). The 47 homogenous plots were 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 & Crundwell, (1991) for mosses , Grolle & Long, (2000) for liverworts. The source of caracterisation of the plant species according to the phytosociological units was Oberdorfer (1983, 1992).

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 (Rhoades, 1982), organic matter by the Walkley and Black's method (Nelson & Sommers, 1982) ; phosphorus by Olsen method (Olesen & Madsen, 2000) ; carbonate content by using dry combustion (Iso 1994, Nelson & 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 & Mulvaney, 1982). 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 between November 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 R i386 (version 4.0.3) software was used for data analysis. To investigate the relationship between the vegetations and environmental factors Ward's Hierarchical Agglomerative clustering techniques (McCune & Grace, 2002) was 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 & 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, The R i386 (version 4.0.3) software. 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 PCA method, whereas species with low variance, often the rare ones, have only minor influence on the method.

RESULTS

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

The edaphic feature showed mean value of conductivity 0.15, C/N 6.43 and organic matter 5.5. The soil of this group was neutral in nature having the man value of pH 7.8. The soil nutrients this group showed the value of phosphorus 0.02 , carbonate potassium 6.03, p 0.3, magnesium 1.76, calcium 39.73 and sodium 0.04 (c mol (+)/mg) respectively (Table 2).

Table 1. Average frequency of understory terrestrial species in the six groups derived from Ward's cluster analysis of the terrestrial vegetation data.

Species	Code	Group number					
		1	2	3	4	5	6
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
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

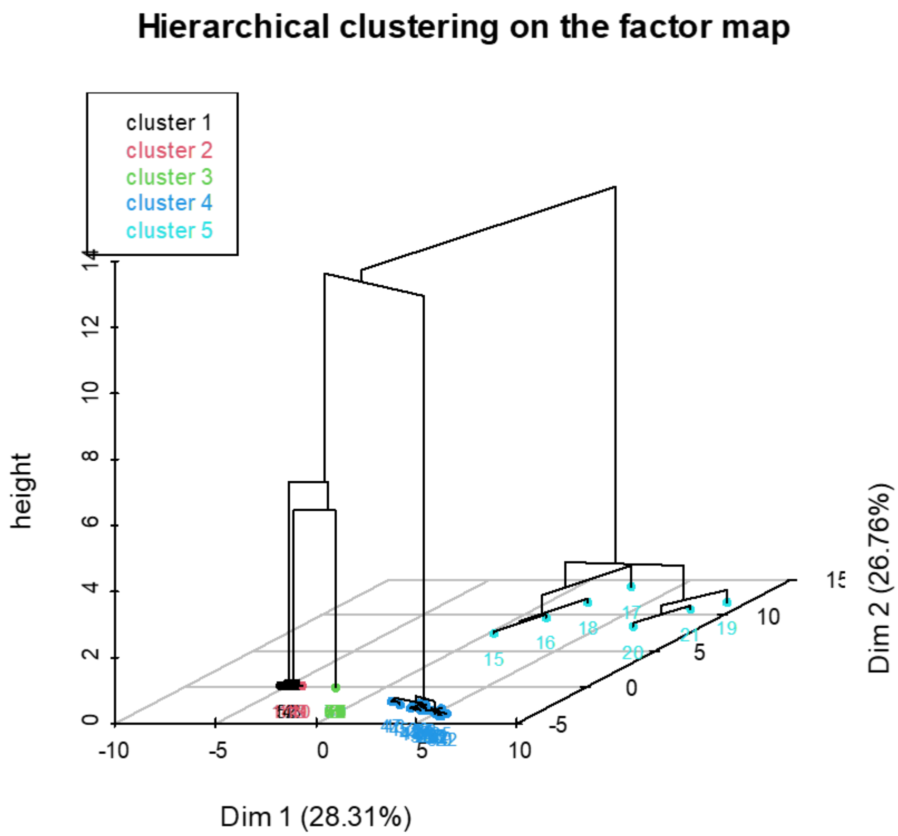

Figure 2. Dendrogram obtained from Ward's Cluster Analysis, using importance value of terrestrial species, showing six distinct groups.

Group (2): This group consists of seven stands having 13 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 Edaphic feature of this group showed mean value of conductivity 0.19, C/N 6.40 and organic matter 5.5 . The soil of this group was neutral in 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 potassium 5.31, p 1.76, magnesium 2.02, calcium 43.13 and 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 6.42 and organic matter 5.5 . The soil of this group was neutral in 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, magnesium and 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,* (Figure 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 pH favoring the appearance of species : *Anthriscus Sylvestris (A.syl)* and *Pallenis spinosa* (*P.spi*). (Figure 3).

Cluster hierarchical classification of aquatic species

The results of cluster hierarchical classification of aquatic species indicated 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 (Figure 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 station 2.

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 49.45 % 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 ammonium were 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 (32.01%) was positively correlated with phosphorous. Stations (3) and (4) project on this component defined by the high rates of dissolved

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	Group 1	Group 2	Group 3	Group 4	Group 5	Group 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

Note : SE = Standard error, (Mean ±SE).

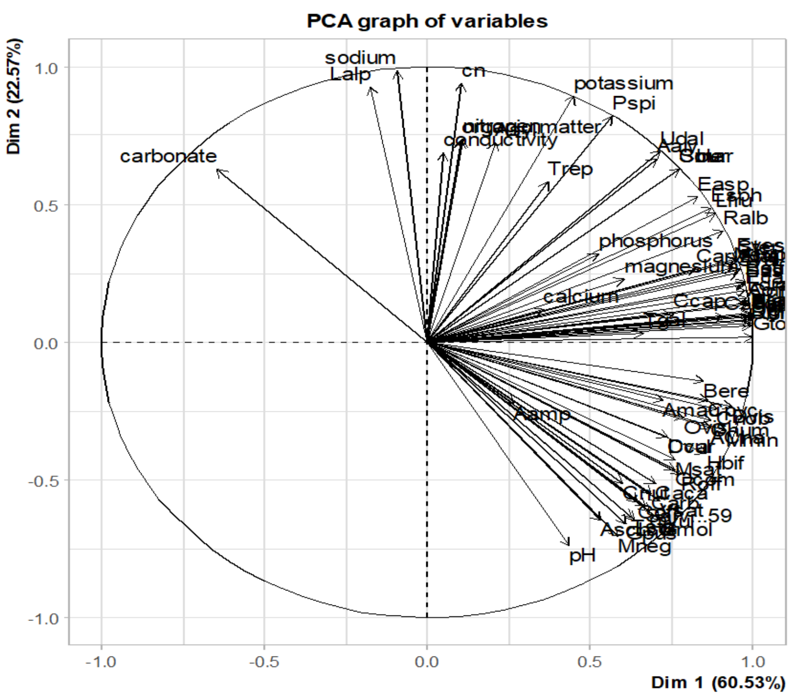

Figure 3 . Terrestrial species against their values for axes 1 and 2.

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 (1) and (2) (Figure 5).

DISCUSSION

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

The plant communities in the study area were divided into six groups of terrestrial vegetation species and three groups of aquatic species, which had substantial differences in their structural requirements. The ordination analysis showed the correlation between wetland vegetation composition, species distribution, and factor environment.

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

In our study, species was found to be related to organic matter 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 ecological species 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 al.*,

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	0.02
Chlorides [mg dm^{-3}]	580	547	581	520

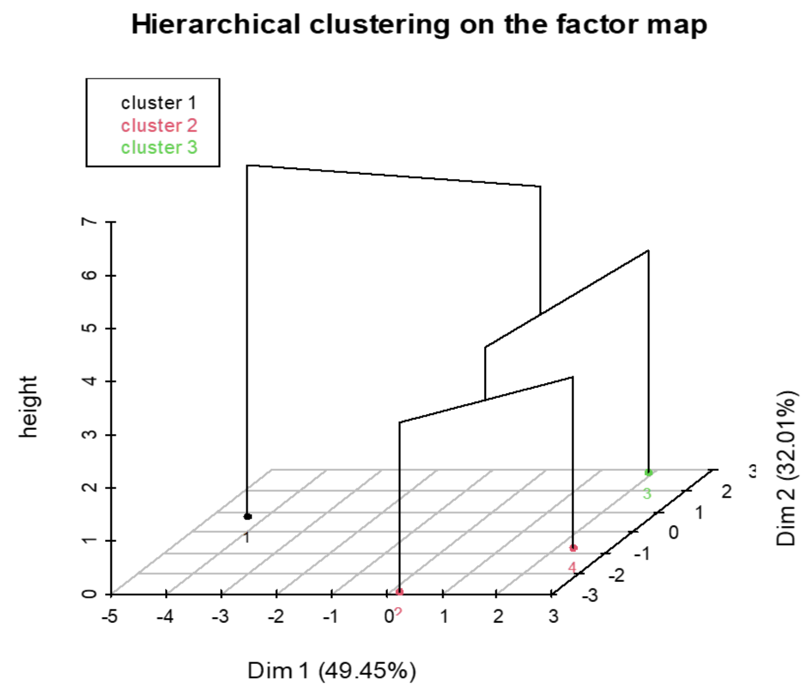

Figure 4. Dendrogram obtained from Ward's Cluster Analysis, using importance value of aquatic species

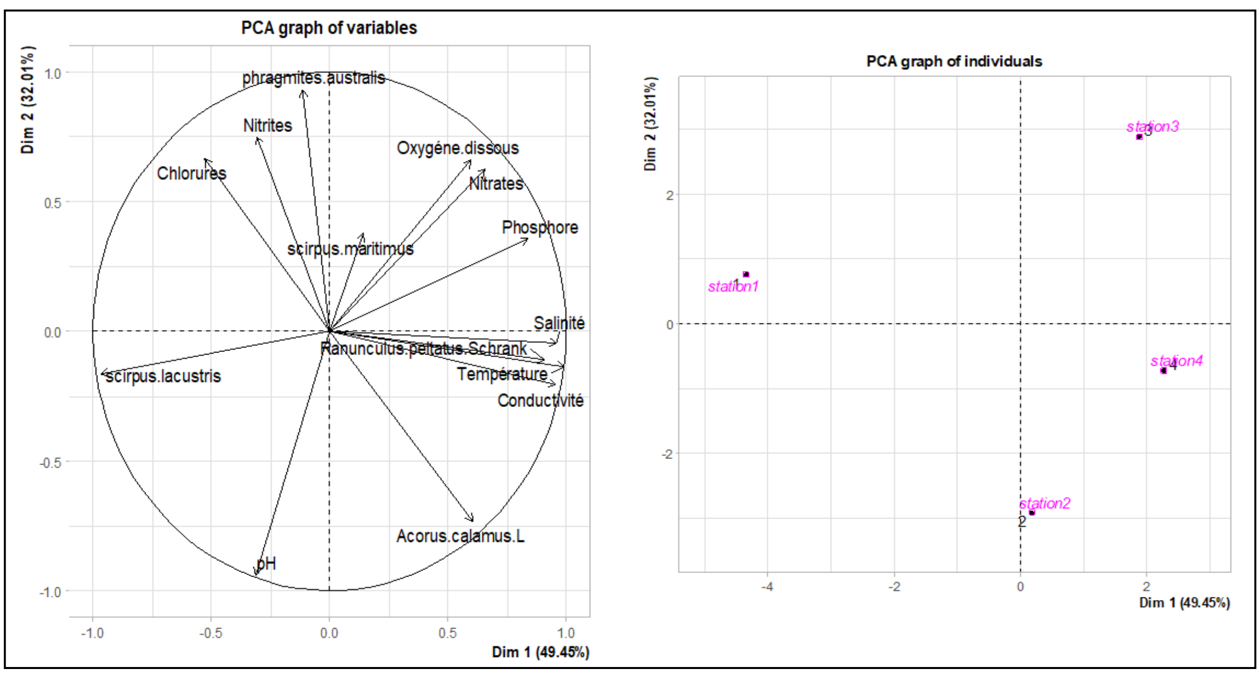

Figure 5. A Five species against their values for axes1 and 2.

2012).

Total potassium was important in structuring Community 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 plant species. Potassium plays a role in regulating photosynthesis, carbohydrate transport, protein synthesis, and other important physiological processes. (Gierth and Mäser, 2007, Britto and Kronzucker, 2008, Szczerba *et al*., 2009).

In our study terrestrial vegetation 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 ammonium had 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 Santamaria 2001 , Olesen and 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 reported that ammonium is an important source of nitrogen on the physiology of plants (Lachmann *et 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. We found that the most common species in the study area are: *Erigeron canadensis, Erigeron sumatrensis , Galactites tomentosus Chamaemeluum nobile, Carduus acanthoides, Carduus nutans, Carduus pycnocephalus, Cirsium vulgare and Crepis capillaris.* The plant species of the study area are currently threatened by Agriculture and water pollution which are the main causes of low diversity in the area. Therefore, this result should be taken for the conservation of that area, so as to protect the natural flora of the area which is full of various economically important plant species and is home to wild fauna as well.

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