Analysis of vegetation assemblage in the salted plain of the lower Chelif, Algeria

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Abstract: In order to establish the relationships between the plants communities and environmental gradients that prevail in the arid plain of the lower Cheliff, one of the largest salted alluvial plain in North Africa, we examined vegetation composition and the environmental variables, using 20 species sampled in 111 stands, followed by a direct gradient analysis. Classification of the vegetation using modified TWINSPAN classification resulted in the recognition of four vegetation units, each of these four units with a definite floristic composition, highly significantly different according to ANOSIM test, was linked to a specific habitat. Multivariate analyses including detrended correspondence analysis (DCA) and correspondence analysis (CCA) showed that vegetation distribution pattern was mainly related to conductivity and soil structure. CCA axis 1 (45.7% of variance explained) was mainly positively correlated to conductivity, Na^+, clay and Ca^{++}, with an exclusive appearance of halophilous species characteristic of the extreme salinity conditions. While it was negatively correlated mainly with soil structure and pH, these conditions were accompanied by the highest plant diversity in the study area, with the appearance of two vegetation units, adding up 13 species belonging to 8 families. CCA axis 2 (20.1% of variance explained) was positively correlated with soil structure and Na^+, while it is negatively correlated mainly with Ca^{++}, with the occurrence of three species indicating the worst soil structure conditions.

Keywords: Anosim, Conductivity, Correspondence analysis, Twinspan, Vegetation units.

Introduction

The vegetal association is a plant community, characterized by definite floristic and sociological features and grows in uniform habitat conditions (Flahault & Schroter, 1910). As defined by (Westhoff & van der Maarel, 1973), these plant communities are recognized by diagnostic species, with a distinct concentration in a particular vegetation unit (Chytry & Tichy, 2003). Their presence or abundance is considered to indicate certain site conditions. Indeed, vegetation presence or absence is controlled by environmental variables such as soil, topography, and climate (McDonald et al., 1996). Among these different environmental factors, soil is normally of great importance. Using vegetal species as bio-indicators can be the most important tool to assess soil conditions (Wang, 1995). Our study was carried out along the lower Chelif plain, one of the largest salted alluvial plains in North Africa, characterized by particular edaphic constraints, harsh climatic adversities, and suffering from serious soil degradation. The apparent structural simplicity of plant communities in this area provides an ideal model to study the relationship between edaphic factors and plant species. The main purpose of this research was to determine, the strongest edaphic factors affecting the occurrence of vegetal species, to extract the main vegetation units independently to the site conditions, and confront them to the edaphic factors characterizing the lower-Cheliff. Understanding relationship between ecological variables and plant species in this harsh ecosystem helps us to apply these findings in management, reclamation, and development of similar regions.

Material and methods

Study area

Covering approximately 500 km2 the lower-Cheliff is one of the largest salted alluvial plains of north-western Algeria (Figure 1), it's about 35 km inland from the Mediterranean Sea, with an average altitude of 70 m. The plain is a syncline framed by salted marls hills (MC Donald & B.N.E.D.E.R 1990). These geological characteristics, accentuated by an arid climate with an average annual temperature of 20° C, a dry period of 7 months, frequent droughts, and minimal precipitation (approximately 250 mm/yr), explain the high salinity conditions of the plain.

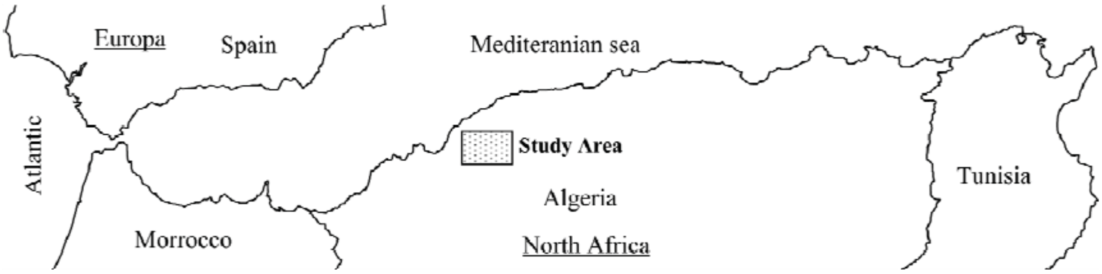

Figure 1. Location of the study area in northern Algeria.

Soil and vegetation sampling

Phytosociological sampling was recorded during spring 2010 and 2011, by using the Braun-Blanquet seven degree scale (Van der Maarel, 1979). A total of 111 relevés were recorded adding up 30 species among which 10 rare species were excluded from analysis. For constrained ordination methods, a total of 111 soil samples were also collected, soil variables analysed were texture, soil structure (MWD), pH, electrical conductivity (ECe), calcium carbonate (CaCO3), Ca^{++}, Cl^{-}, and Na^{+}. Each sampling unit location (latitude, longitude, and altitude) were recorded using a GPS receiver.

Data analysis

To simplify the continuum of species composition present in the study area and to aid our understanding of species–environment relationships, relevés were classified into a few groups by modified two-way indicator species analysis (TWINSPAN) classification (Rolecek et al., 2009). Thus, by using this algorithm, homogenous groups are formed; the characteristic species of each group were identified by using the phi coefficient of association (Chytry et al., 2002). This coefficient is a statistical measure of association which can be used as a measure of fidelity. It is defined as:

$$\Phi = \frac{N.n_p - n.N_p}{\sqrt{n.N_p\,(N-n).(N-N_p)}}$$

N = number of relevés in the data set; Np = number of relevés in the particular vegetation unit; n = number ofoccurrences of the species in the data set; np = number of occurrences of the species in the particular vegetation unit.

To examine variation in vegetation assemblage structure among groups, we performed an ANOSIM (Legendre & Legendre, 1998) by using Bray-Curtis similarity. Finally, in order to establish the main links between environmental variables and vegetation, first, a co-linearity test showed a strong correlation coefficient between sands and silt, Na^{+} and Cl^{-}. Therefore, we chose to eliminate Cl^{-} and silt. Then, the remaining variables were log-transformed. The most significant variables according to the individual preselection were, ECe, MWD, pH highly significant ($P < 0.01$), and clay significant ($P < 0.05$), the remaining variables (Na^{+}, sand, CaCO3, Ca^{++}) were not significant. In order to perform a direct gradient analysis, a detrended correspondence analysis (DCA) (Hill & Gauch, 1980) showed that the longest gradient was 5.78, thus, the best results are shown by canonical correspondence analysis CCA (ter Braak, 1986 ; Leps & Smilauer, 2003). However, CCA is useful technique strongly affected by double zeros (Zuur et al., 2007). In this case, according to reference (Legendre & Gallagher, 2001), the best option is to apply a special Chord (Orloci, 1967) or Hellinger (Rao, 1995) transformation.

Results and discussion

Classification of vegetation

The application of modified TWINSPAN classification on the 20 species enabled us to distinguish four vegetation units (Table 1, Figure 2). These groups were named according to their leading dominant species (those with the highest phi coefficient value) as follows: (A) *Spergularia marina*, (B) *Erodium cicutarium*, (C) *Melilotus officinalis*, and (D) *Bellis perennis*. Each of these four vegetation units could easily be linked to a habitat type.

Vegetation unit A: The 29 samples belonging to this community were characterized by the highest conductivity, Na^{+}, Ca^{++}, and clay, the lowest pH and relatively low soil structure. The phi coefficient classification showed that this vegetation unit was composed of four diagnostic species, belonging exclusively to Chenopodiaceae and Caryophyllaceae, characteristic of the extreme salinity conditions.

Vegetation unit B: In contrast to the previous vegetation unit, this group of 7 samples presented the best soil structure, the highest pH and sand percentage, the lowest conductivity, Ca^{++}, and clay.

Vegetation unit C: This community included 41 samples moderately salty, with alkaline soil reaction, good soil structure, and the lowest Na^{+} quantity. This vegetation unit includes the largest number of diagnostic species belonging to 5 different families (Fabaceae, Asteraceae, Bromeliaceae, Primulaceae, Plantaginaceae).

Vegetation unit D: This community was represented in 34 samples, characterized by the worst soil structure, the lowest CaCO3 percentage, high clay percentage, high Na^+ quantity, and moderate salinity.

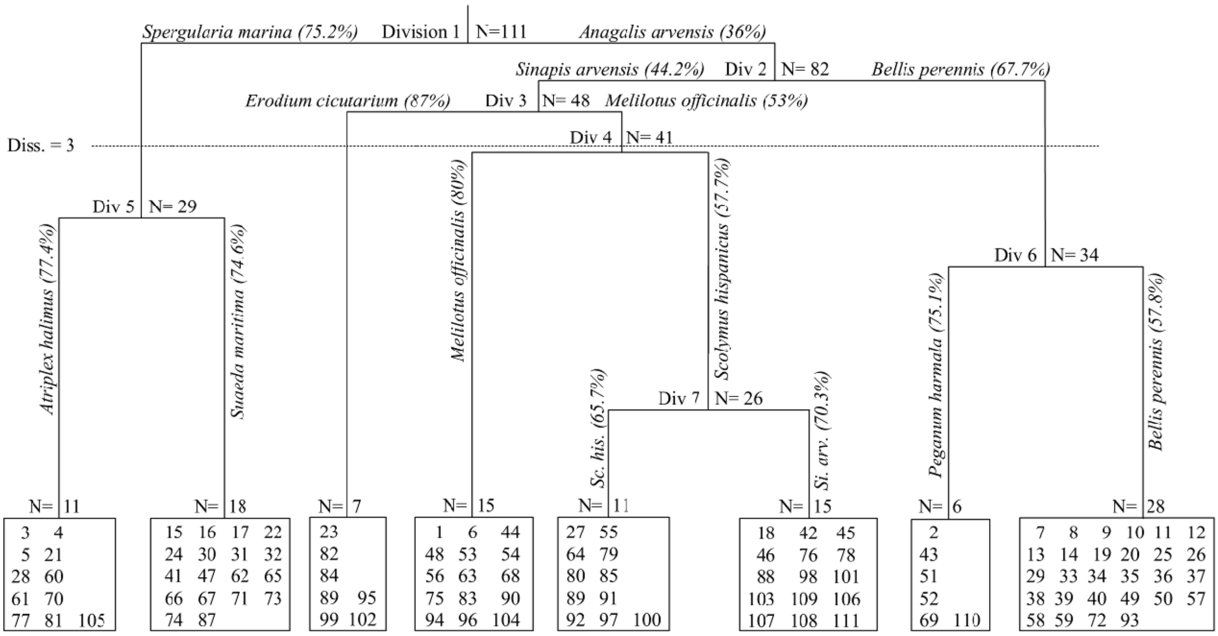

Figure 2. TWINSPAN classification of 111 plots. N indicates the number of plots and the value between brackets represent the phi coefficient value in percent.

Table 1: Table of 111 relevés and 20 species, based on fidelity coefficient. Diagnostic species (* p < 0.05, ** p < 0.01, *** p < 0.001) are those with significant φ value according to Fisher's test.

Vegetation unit A (*29 Relevés*)	*Vegetation unit B* (*7 Relevés*)	*Vegetation unit C* (*41 Relevés*)	*Vegetation unit D* (*34 Relevés*)
Spergularia marina (71.9***) *Suaeda maritima* (59.8***) *Atriplex halimus* (46.7***) *Arthrocnemum macrostachyum* (28.2*)	*Erodium cicutarium* (87***) *Onopordum acanthium* (75.1***) *Foeniculum vulgare* (42.1*) *Torilis nodosa* (33.1*) *Lolium multiflorum* (24.3*) *Cirsium vulgare* (17.1)	*Melilotus officinalis* (53***) *Scolymus hispanicus* (44.1***) *Sinapsis arvensis* (36.8***) *Calendula arvensis* (36.2***) *Anagallis arvensis* (33.3**) *Scorpiurus muricatus* (17.4) *Plantago lanceolata* (15.4)	*Bellis perennis* (70.5***) *Phalaris arundinacea* (51.4***) *Peganum harmala* (31*)

Soil characteristics of each of the four vegetation units were analysed through ANOVA (Table 2). Results indicated that among all measured soil parameters, conductivity and pH showed highly significant differences between groups (P < 0.01), Na^+ and soil structure (MWD) showed significant differences (P < 0.05), meaning that vegetation composition and distribution in the lower Chelif was highly related to conductivity, pH, soil structure, and Na^+.

Table 2 : Mean values with mean standard error and ANOVA F-values of the environmental variables in the sites representing the four groups obtained by TWINSPAN.

	Group A	Group B	Group C	Group D	F	P
ECe	16.5 ± 1.6	3.3 ± 1	6.5 ± 1.13	8.5 ± 0.94	14.57	0.0001
pH	7.8 ± 0.03	8.1 ± 0.1	8.0 ± 0.05	7.9 ± 0.04	10.23	0.0001
Na^+	4 ± 0.47	2.8 ± 0.6	2.8 ± 0.16	3.2 ± 0.27	3.07	0.03
MWD	0.8 ± 0.04	1.0 ± 0.1	0.9 ± 0.05	0.8 ± 0.03	2.87	0.04
CaCO3	17.7 ± 0.5	19.1 ± 2	18.1 ± 0.5	16.6 ± 0.4	2.11	0.103
Ca^{++}	0.5 ± 0.1	0.3 ± 0.1	0.4 ± 0.04	0.5 ± 0.04	1.88	0.137
Clay	5.9 ± 0.5	4.7 ± 0.7	4.9 ± 0.33	5.7 ± 0.19	1.63	0.186
Sand	23.5 ± 1.2	26.6 ± 3	25 ± 1.2	24.2 ± 0.86	0.56	0.642

Similarity analysis

Similarity analysis test (ANOSIM) (Table 3) showed highly significant differences ($P < 0.01$) in taxonomical composition between (A, B), (A, C), (B, C), (C, D), and significant differences ($P < 0.05$) between (A, D) and (B, D), these significant differences indicate the total absence of overlap between vegetation assemblages. These results were supported by high significant R values, indicating that similarities between relevés within groups are higher than those between relevés from different groups. Thus the result of similarity analysis (ANOSIM) showed clear differences in taxonomical composition among the different groups.

Table 3: Results of similarity analysis according to Bray-Curtis similarity with p-value (higher matrix) and R-value (lower matrix).

Bray-Curtis similarity		P values (** p < 0.01; * p < 0.05)			
		A	B	C	D
R values	A		0.005**	0.003**	0.03*
	B	0.788		0.005**	0.01*
	C	0.859	0.395		0.008**
	D	0.694	0.836	0.486	

Canonical correspondence Analysis

The marginal effects indicated that conductivity was the best explanatory variables, followed by soil structure, Na^+, pH, Ca^{++}, and clay, whereas CaCO3 and sand plays a secondary role. The variance of species occurrence data explained by each variable according to the partial CCA was in the following order: ECe = 5.3%, soil structure = 3.3%, pH = 3.1%, Na^+ = 2.8%, Clay = 2.3 %, Ca^{++} = 2.2%, CaCO3 = 1.1%, and Sand = 1%. This means that the distribution of vegetal species in the lower-Cheliff plain is strongly correlated to conductivity, soil structure and pH.

The variance of species-environment relationship, explained by the first two canonical axes of the correspondence analysis was 65.8%. The first axis with 45.7% of variance explained, was mainly positively correlated to conductivity, and then to Na^+, clay, and Ca^{++}, with the occurrence of vegetation unit A composed exclusively of Chenopodiaceae and Caryophyllaceae, while it was negatively correlated mainly with pH and subsequently to soil structure, these conditions were accompanied with the highest plant diversity in the study area (Figure 3), with the appearance of vegetation units B and C. The second axis with 20.1% of variance explained was positively correlated with soil structure and Na^+, while it was negatively correlated mainly with Ca^{++}, with the occurrence of vegetation unit D, indicating the worst soil structure.

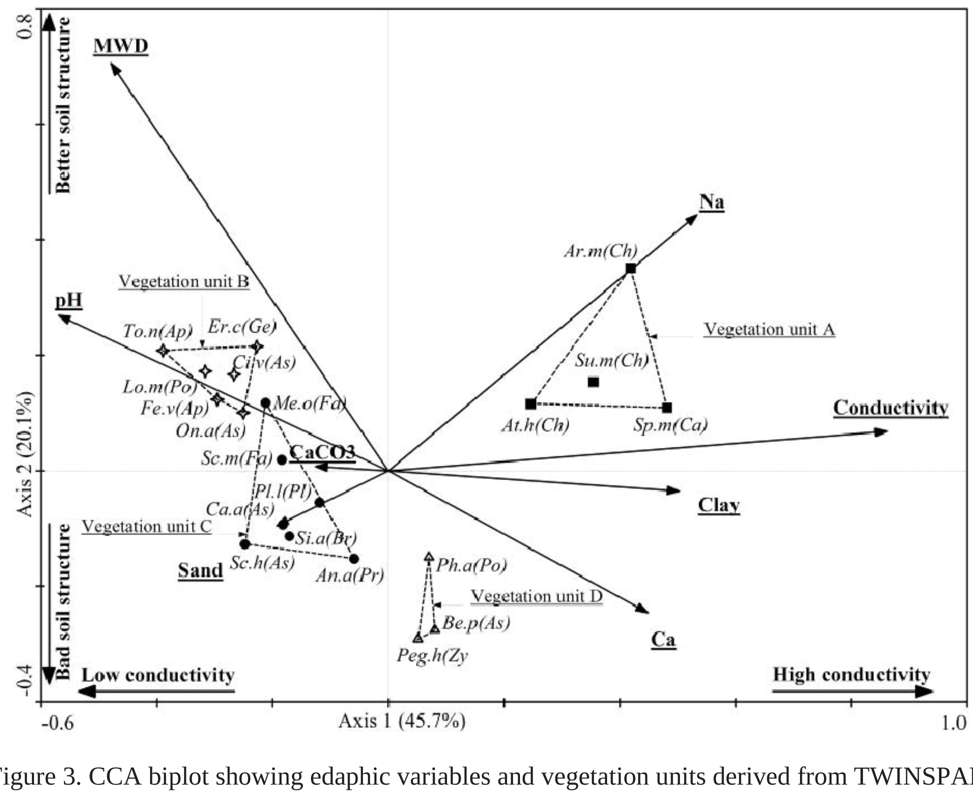

Figure 3. CCA biplot showing edaphic variables and vegetation units derived from TWINSPAN.

Predicting vegetation occurrence according to edaphic variables

A Gauss model (Jongman et al., 1995) was used to examine the relationships between the different vegetation units occurrence, and abiotic habitat variables, especially the most influencing variables. Electrical conductivity, pH, Na^+, and soil texture were all statistically significant predictors of species occurrence ($P < 0.01$) according to chi-square approximation. Gauss results (Figure 4) showed that the optimum of vegetation unit A, with respect to electrical conductivity was greater than 35 mmhos. Vegetation unit B was highly sensitive to conductivity with an optimum of only 1 mmhos, whereas the occurrence of vegetation unit C and D increased to an optimum, respectively of 5.8 and 10.5 mmhos followed by declining occurrence, the same behavior towards conductivity was shown towards Na^+, the highest optimums were shown respectively by vegetation unit A and D, and the lowest optimums respectively by vegetation unit C and B. The best soil structure was indicated by vegetation unit B and C with an optimum of 2 mm each, and the worst soil structure was indicated respectively by vegetation unit A (0.45 mm) and unit D (0.65 mm). Slightly alkaline soil reactions were shown by vegetation unit B and C (8.78), whereas vegetation unit A and D prefer neutral pH.

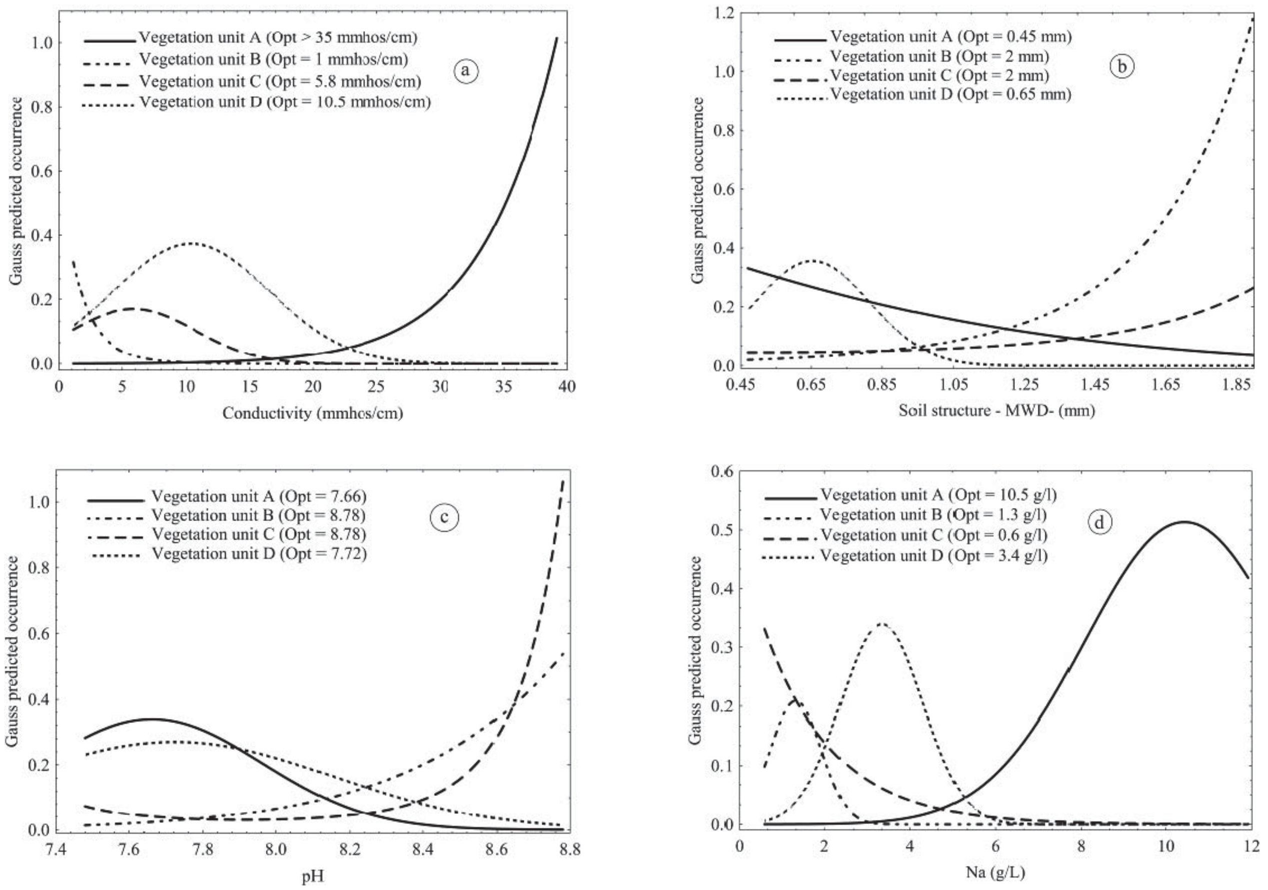

Figure 4. Predicted occurrence of the four vegetation units as obtained by Gauss model according to a. conductivity, b. soil structure, c. Na^+, d. pH

Conclusion

The lower Chelif represents a weakened ecosystem, characterized by particular edaphic constraints and harsh climatic adversities. Traditional methods of evaluation of site conditions are expensive and time consuming, especially in areas as large as the Lower-Cheliff; thus, recognition of vegetation ecology is the easiest way of decreasing cost and saving time in the assessment of environmental conditions. The present study provides fundamental information on the edaphic factors affecting vegetation assemblage and distribution in one of the largest arid area in North Africa. We distinguished vegetation units composed of halophilous species, distributed throughout the salty grounds and more diverse vegetation units, very sensitive to salinity, occupying unsalty to slightly salty grounds. Thus, the assessment of plant communities was a useful tool to classify salinity, especially in terms of revealing the spatio-temporal changes of this variable. Understanding relationships between environmental variables and vegetation distribution in this area helps us to apply these findings in management, reclamation, and development of arid and semi-arid ecosystems.

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