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Seasonal Evolution Study of Soil Salinity under Mediterranean Condition

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Abstract. The objective of this work is to study the seasonal evolution of soil salinity (Solonchak) in the region of Bas-Chéliff at the scale of three soil profiles. It is therefore a question of characterizing the soil solution, defining the distribution profiles of salts in the soil, determining the speed of salinization and determining the temporal evolution of salinity between the dry season and the wet season. Data analysis revealed that all three profiles experienced salinization during the dry season compared to the wet season. the three profiles are characterized by a predominantly silty-clayey texture and an average limestone content. The chemical composition of the soil solution is dominated by chlorides and sodium. Principal component analysis (PCA) revealed that the chemical elements of the soil solution (Na^+ and Cl^-) have the most influence on the variability of salinity. The three profiles show salinization between the wet and dry season. This salinity occurred at a speed which is respectively 8.47dS/m/month, 8.5 dS/m/month and 3.1 dS/m/month for profiles 1, 2 and 3. We can conclude that the three profiles suffered salinization during the dry season.

Keywords. Salinity, Seasonal evolution, Solonchak.

1. Introduction

Salinization is defined as being the pedological process according to which the soil is enriched abnormally in soluble salts, thus acquiring the saline character [1].
Soil salinity also contributes to desertification and causes a significant decrease in plant resistance to various stresses, which causes a regression in agricultural production [2,3]. Similarly, salinization is a major constraint on a global scale. It affects approximately, 900 million hectares of land, in more than 100 countries are affected by salinization and sodicity [4].
However, in Algeria, salinity is a major problem affecting 3.2 million hectares [5,6]. Salinization in soil can occur without human intervention, as is the case with primary salinity, and can also result from uncontrolled irrigation practices in the case of secondary salinization [7,8]. According to [9,10,11] the salty soils of Algeria have a higher degree of belonging to Calcisols.
Similarly, saline soils can be subdivided into three categories: saline soils, saline alkali soils, and alkali soils [12].This subdivision is essentially based on the level of salinity of the soil solution (expressed by the electrical conductivity of the saturated paste extract), and the level of sodicity of the adsorbent complex (expressed by the rate of exchangeable sodium).
The most common salts in soils of arid and semi-arid regions are sodium chlorides and calcium sulphates [6].

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The problem of soil salinization is particularly important in the Bas-Chéliff plain and the risk of insidious and rapid salinization is then high. Indeed, it is a region characterized by low rainfall and high evapotranspiration, more or less heavy irrigation water depending on the season and the origin of the water (surface or underground). Thus, this risk of salinization is accentuated by the presence of a very shallow salt water [13]. In Bas-Cheliff, non-saline soils represent 16% of the total area, moderately saline soils represent 22%, saline soils represent 30% and very saline soils occupy 32% of the total surface [14].
The objective of this work relates to the evaluation of the temporal evolution of the state of salinity of the grounds between the wet season and the dry season, It is thus a question of characterizing the solution of the grounds, to define the profiles of distribution of salts in soils, determination of the rate of salinization. It is also a question of defining the temporal evolution of salinity between the dry season and the wet season in the region of Bas-Chéliff.

2. Materials and Methods

2.1. Location of the Study Area
The Bas-Chéliff plain, which extends over more than 60,000 ha, is located at the northern end of the Chéliff basin (north-west of Algeria), about 250 km west of Algiers and 35 km as the crow flies from the Mediterranean.

2.1.1. The Climate
The climate is semi-arid characterized by 253 mm rain/year and a very strong potential evapotranspiration (ETP = 1500 mm/year) calculated by Penman equation. The maximal summer and winter

2.1.2. Methodology
This work aims to study the temporal evolution of soil salinity in the Bas Chélif region. It is a question of characterizing the solution of the soils, of defining the distribution profiles of the salts in the soils, of determining the rate of the monthly salinization.
The average EC (Electric Conductivity) of the profile is calculated according to the following formula:

$$\frac{\sum(\,EC\ of\ each\ horizon\ \times\ horizon\ thickness)}{profile\ thickness}$$

The difference in the average salinity of the profiles is obtained by difference between the values of the EC of the wet season and that of the EC of the dry season. The monthly salinization rate is obtained by dividing the difference by time (months). The duration of the wet season in the Rélizane region is 4 months and that of the dry season is 8 months. Therefore, when it comes to studying the rate of salinization between the wet season and the dry season, the difference is divided by 8.
We studied three profiles (P) (P1, P2 and P3) (fig. 1) during wet seasons and dry season. The choice of these profiles meets the diagnostic criteria of the Solonchak group as defined by the WRB classification [15].
According to the WRB (2015) a Solonchak must be characterized by the presence of a salic horizon. This one must have on all its depth:

- An electrical conductivity (EC) of the saturated paste extract greater than 15dS /m at 25C° at any time of the year.
- An EC of more than 8 dS/m at 25C° if the pH (H2O) of the saturated pulp extract exceeds 8.5 (for alkaline carbonate soils) or is less than 3.5 (for acid sulphate soils) .
- A thickness of at least 15 cm.
- A product of thickness in (cm) and CE in (dS/m) greater than or equal to 450 or greater
- Absence of a sulfuric (thionic) horizon.

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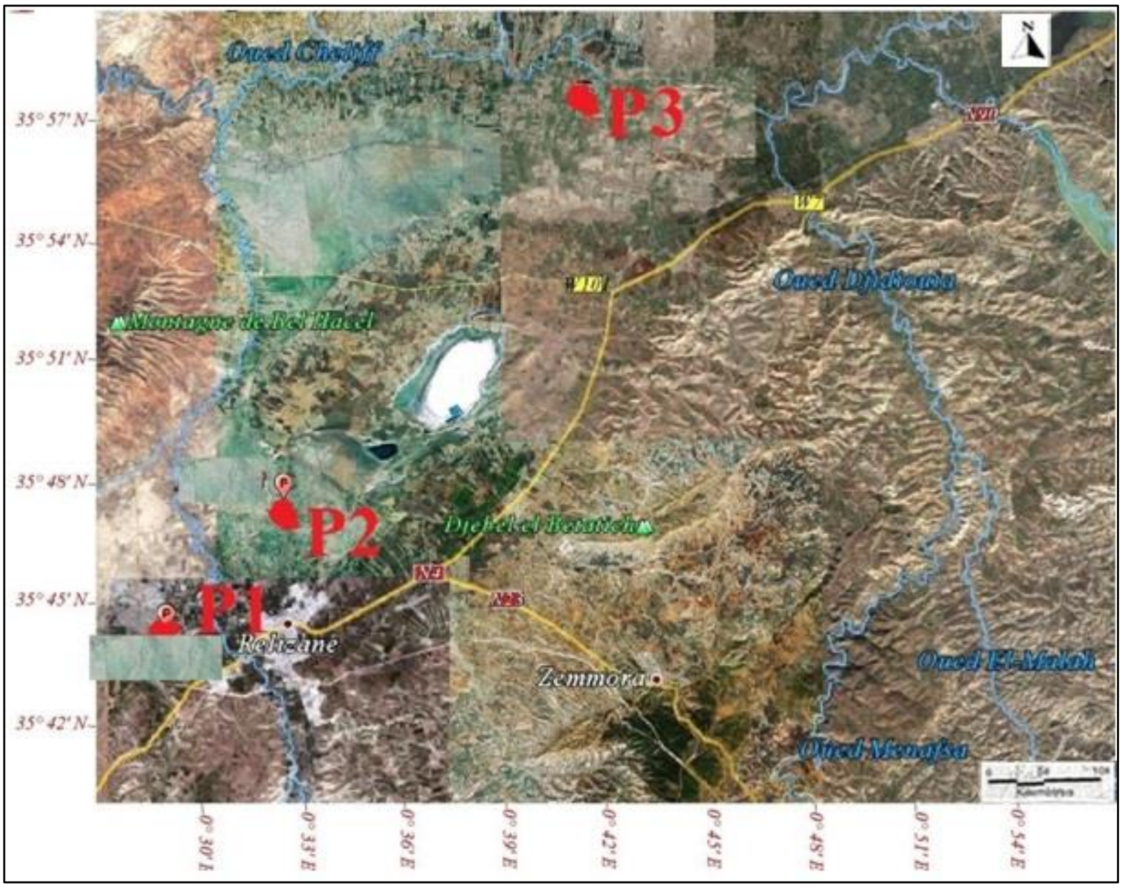

Figure 1. Profiles (P) location map (red spots).

2.1.3. Soil Analysis

For the soil we used the data obtained by the following methods:

- Particle size analysis: international Robinson pipette method.
- Electrical conductivity (EC) (saturated paste extract): electrical method.
- The pH: carried out on the extract of the saturated paste.
- Total limestone: volumetric method using Bernard's calcimeter.
- Gypsum: dosage by attack then precipitation, with barium chloride.

2.1.4. Soil Solution Analyzes

- Electrical conductivity (EC): electrical method.
- Sulphates: gravimetric method by precipitation (barium chloride).
- Carbonates and bicarbonates: volumetric method, determination by an acid solution.
- Chlorides: volumetric method using silver nitrate.
- Sodium and potassium: by flame photometry.
- Calcium and magnesium: by atomic absorption photometry.

In order to better analyze the data, we used PCA (principal component analysis). This analysis allows us to determine the anions and cations of the solution of soil that have the most influence on the variation in salinity. For this purpose, we used the Excel-Stat software.

3. Results

3.1. Analysis of the Constitutions of Profile 1.

The results of the Profile 1 analyzes are shown in Table 1.

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Table 1. Analytical results of profile 1 constituents.

Horizons	Depth (cm)	Gypsum (%)	$CaCO_3$ (%)	OM (%)	Clays (%)	Silts (%)	Sands (%)
H1	0-17	0.71	23.51	0.82	52.1	42.4	1.3
H2	17-33	0.81	20.27	2.47	57.9	35.3	1.7
H3	33-45	2.678	21.89	0.17	48.1	42.3	5.4
H4	45-110	0.88	20.27	/	30.6	58.4	5.9

3.1.1. Granulometric Composition

The particle size results (Table 1) show a dominance of the silt fraction (58.4 > silts (%) >35.3), but also a dominance of the clay fraction (57.9 > clays (%) >30.6) in the set of horizons. The sandy fraction is very low, between 1.3% and 5.9%. Therefore, the texture of the profile studied consists essentially of silt and clay. As a result, the texture is silty-clayey.

3.1.2. The Total Limestone

The calcium carbonate contents are high, varying between 20.27% and 23.51% (table 1). Therefore, the studied profile is moderately calcareous.

3.1.3. Gypsum

Gypsum contents are very low throughout profile 1, varying between 0.71% and 2.67% (Table 1). These results demonstrate that the profile studied is not gypsum.

3.1.4. Organic Matter (OM)

The rate of organic matter is very low throughout the profile, these contents vary from 0% to 2.47% (Table 1). So we conclude that profile 1 is low in organic matter.

3.2. Analysis of the Constitutions of Profile 2.

The analytical results of profile 2 are presented in Table 2.

Table 2. Analytical results of profile 2 constituents.

Horizons	Depth (cm)	Gypsum (%)	$CaCO_3$ (%)	MO (%)	Clays (%)	Silts (%)	Sands (%)
H1	0-10	0.34	18.09	2.47	38.8	42.0	13.5
H2	10-19	0.65	22.29	/	42.0	51.2	2.7
H3	19-28	0.66	19.0	/	30.0	63.2	3.7
H4	28-70	0.79	21.48	/	32.0	54.6	8.3

3.2.1. Granulometric Composition

According to table 2 and figure 1, the particle size composition of the different horizons of the profile is dominated by silts (63.2 > silts(%) > 42.0), and clays (42.0 > clays(%) > 30) the sands present a small proportion varies between 2.7% and 13.5%. In general, the texture of the profile studied is silty-clayey.

3.2.2. The Total Limestone

The calcium carbonate contents are high in all the profile horizons, they vary between 18.09% and 22.29% (Table 2). These results show that the studied profile is moderately calcareous.

3.2.3. Gypsum

The gypsum contents vary little throughout profile 2, they oscillate between 0.34% and 0.79% (Table 2). This indicates that the profile is very poor in gypsum.

3.2.4. Organic Matter

The OM rate is very low in profile 2, it is 2.47% in the surface horizon and zero in the other horizons (Table 2). These results show that the studied profile is poor in organic matter.

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3.3. Analysis of the Constitutions of Profile 3

The analytical results of profile 3 are mentioned in Table 3.

Table 3. Analytical results of profile 3 constituents.

Horizons	Depth (cm)	Gypsum (%)	$CaCO_3$ (%)	OM (%)	Clays (%)	Silts (%)	Sands (%)
H1	0-17	1.5	17.02	2.47	47.7	47.5	<1
H2	17-50	/	17.83	2.4	54.0	46.5	<1
H3	50-82	/	28.47	/	55.8	41.0	<1
H4	82-115	/	18.44	/	55.8	40.0	<1

3.3.1. Granulometric Composition

Table 3 shows that the clays are dominant compared to that of the silts in all the horizons of the profile, concerning the sandy fraction is practically nil (<1%). As a result, the texture is clayey-loamy.

3.3.2. Total Limestone

The calcium carbonate contents are high in all profile horizons, they vary between 17.02% and 28.74% (Table 3). These results show that profile 3 is calcareous.

3.3.3. Gypsum

The gypsum content is zero in the three horizons (H2, H3, H4), only the first horizon which records a low proportion (1.5%) (table 3). These results show that the studied profile is not gypsum.

3.3.4. Organic Matter

The OM rate of profile 3 is very low, it is 2.4% in the horizons (H1, H2) and zero in the other horizons (table 3). organic.

3.4. Soil Solution Analysis

3.4.1. Analysis of the Soil Solution of Profile 1

The analytical results of the soil solution of profile 1 are presented in Table 4.

Table 4. Analytical characteristics of the soil solution of profile 1.

Horizons	pH	Na^+ (meq/l)	K^+ (meq/l)	Ca^{++} (meq/l)	Mg^{++} (meq/l)	Cl^- (meq/l)	HCO_3^- (meq/l)	SO_4^{--} (meq/l)	SAR
H1	7.63	135.6	10.16	30.64	50.25	200	2	30	18
H2	7.45	200.65	3.82	26.67	50.25	240	2	30	32
H3	7.18	208.27	4.00	78.82	135.63	373.91	8	94.2	20
H4	7.3	322.04	4.94	36.92	215.08	539.13	9	80.6	2

SAR: Sodium Absorption Ratio.

Profile 1 salinity values during the wet and dry season are shown in Table 5.

Table 5. Electrical conductivity of soil solution for both wet and dry seasons.

Horizons	Depth (cm)	EC (dS/m)	
		Wet season	Dry season
H1	17	23.5	25.20
H2	16	27.1	74.80
H3	12	41.5	91.60
H4	65	57.4	136.30

3.4.1.1. Salinity

The distribution of salts as a function of depth during the wet season (Table 5 and Figure 2) shows high salinity at the depth horizon (EC=57.4 dS/m). Salinity is relatively low at the surface horizon (EC=23.5dS/m). The saline profile of this wet season is descending.

On the other hand, during the dry season (table 5 and fig. 2) we notice a strong increase in salinity from the first horizon (EC=25.2dS/m) to the last horizon (EC=136.3dS/m).

These results show an increase in salinity at the levels of the depth horizons. The salt profile of profile 1 is descending. In general, this profile is marked by high salinity during the dry season.

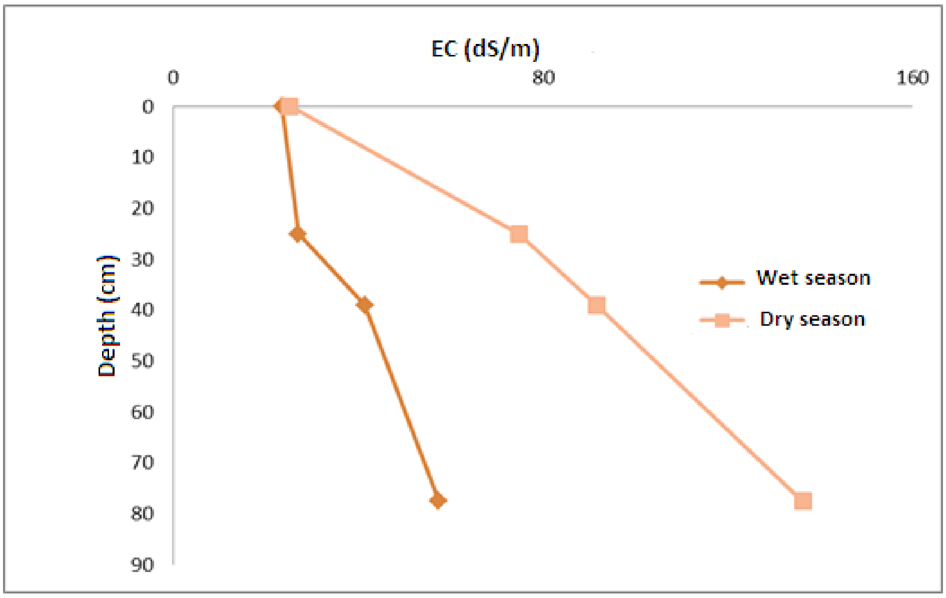

Figure 2. Salt distribution of profile 1 for wet and dry seasons.

3.4.1.2. pH

The pH values vary between 7.18 and 7.63 (Table 4). In general, the pH varies little in the soil. The soil reaction is relatively alkaline.

3.4.1.3. Cations

From table 4 and fig. 3 we notice that:

- The sodium content in the soil solution is high throughout profile1, it varies between 48.81% and 71.30%. Na^{+} is the most abundant cation in profile1.
- The potassium content of the soil solution is very low in all the horizons, it varies between 0.85% and 4.48%.
- The calcium content of the soil solution is low throughout the profile1, it is 6.38% to 18.47%.
- The rate of magnesium in the soil solution varies between 17.86% and 37.15%, Mg^{++} is the cation dominates after Na^{+}.Therefore, the classification of cations according to their predominance is of the type: Na^{+}>Mg^{++}> Ca^{++} >K^{+}.

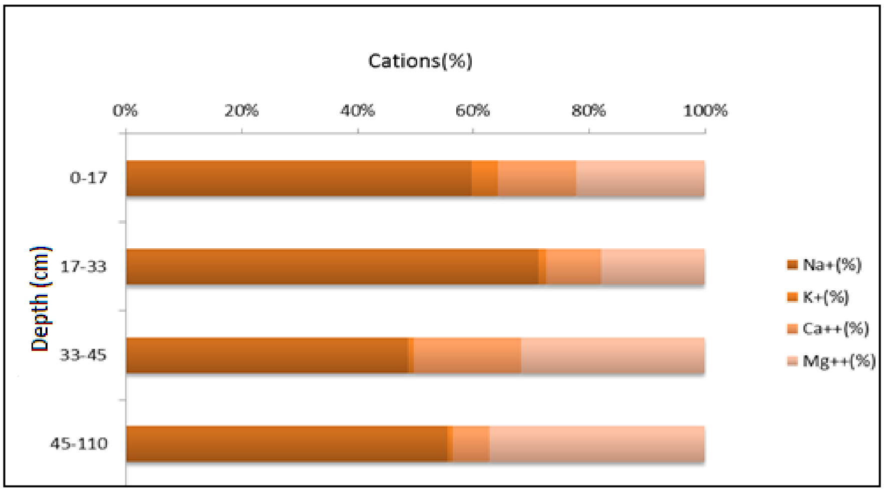

Figure 3. Distribution of cations in the soil of profile1.

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3.4.1.4. Anions

Le Tableau 4 et la Fig. 4 montrent les situations suivantes :

- La teneur en chlore de la solution du sol varie entre une valeur minimale de 78,53 % et une valeur maximale de 85,75 %. Le Cl^- est l'anion dominant du profil2.
- Les teneurs en bicarbonate de la solution de sol sont faibles tout au long du profil 2, elles varient entre 0,73% et 1,68%.
- La teneur en sulfate de la solution du sol varie entre 11,03 % et 19,79 %. SO_4^{--} est l'anion le plus courant après Cl^-. De ce fait, la classification des anions selon leur prédominance est du type : $Cl^- > SO_4^{--} > HCO_3^-$.

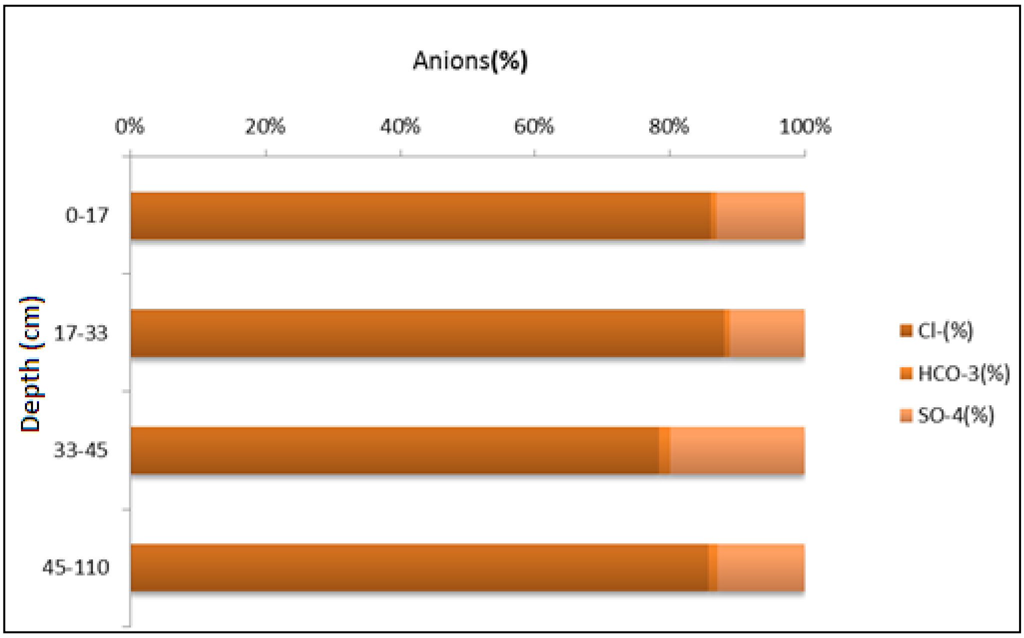

Figure 4. Distribution of anions in the soil of profile 1.

3.4.1.5. SAR

The SAR values are between 2 and 32 (Table 4). We conclude that profile 1 presents an alkalinity risk, except for the last horizon where the alkalinity risk is low.

3.4.2. Soil Solution Analysis of Profile 2

The analytical results of the soil solution of Profile 1 are shown in Tables 6 and 7.

Table 6. Analytical characteristics of the soil solution of profile 2.

Horizons	pH	Na^+ (meq/l)	K^+ (meq/l)	Ca^{++} (meq/l)	Mg^{++} (meq/l)	Cl^- (meq/l)	HCO_3^- (meq/l)	SO_4^{--} (meq/l)	SAR
H1	7.5	248.65	6.24	24.67	101.25	395	1	8.56	31
H2	7.1	16.6	9.23	1.25	5.58	20	6	8.56	8
H3	6.8	70.65	14.45	10.67	25.25	120	3	8	16
H4	7.1	335.8	5.50	38.92	215.08	539	7	8.1	30

Table 7. Electrical conductivity of Soil Solution for Wet and Dry Season of profile 2.

Horizons	Depth (cm)	EC (dS/m)	
		Wet season	Dry season
H1	10	32.7	28.10
H2	09	22.29	138.40
H3	09	19	164.2
H4	42	21.48	69.60

3.4.2.1. Salinity

Salinity values during the wet season (Table 7 and fig. 5) vary between 19 dS/m and 32.7 dS/m. This salinity is very high at the surface (EC=32.7dS/m) and relatively low at the middle part (EC=19dS/m). The general tendency of the salt profile is concave type for the wet season.

However, during the dry season (Table 6 and Figure 5) we see a strong increase in salinity from the first horizon (EC=28.10 dS/m) to the third horizon (EC=164.2dS/m). The salinity decreases at the level of the last horizon (EC=35.42dS/m). As a result, the saline profile is of the convex type.

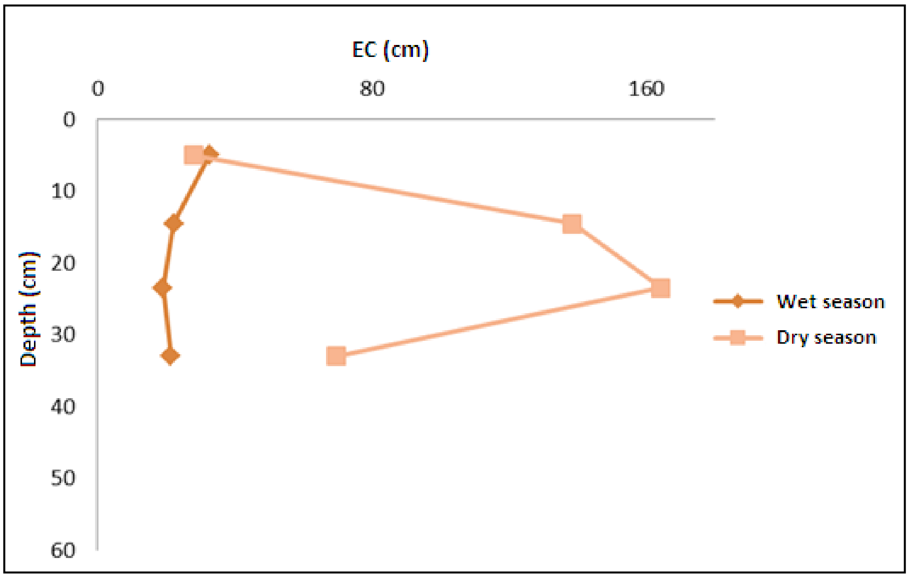

Figure 5. Salt profile of profile 2 for both wet and dry seasons.

3.4.2.2. pH

The pH values vary between 6.8 and 7.5 (Table 6). Generally speaking, soil reaction is relatively alkaline.

3.4.2.3. Cations

Table 6 and fig. 6 reveal that:

- The sodium content in the solution is very high, it is 50.83% to 65.30%. Na^{+} is the dominant cation in profile 2.
- The potassium content of the soil solution varies between 0.92% and 28.26% throughout profile 2.
- The calcium content of the solution is low, it is from 3.83% to 8.86% in the whole profile.
- The magnesium content in the solution of profile 2 varies between 17.08% and 36.13%. The Mg^{++} cation is the most represented cation after Na^{+}.

As a result, the classification of cations according to their predominance is of the type: $Na^{+} > Mg^{++} > Ca^{++} > K^{+}$.

3.4.2.4. Anions

Table 6 and fig. 7 show that:

- The chlorine levels of the soil solution are very high. They vary between a minimum value of 57.87% and a maximum value of 97.64%. Cl- is the dominant anion in profile 2.
- The bicarbonate contents of the soil solution vary between 0.25% and 17.36% in all the horizons.
- Sulfate contents range between 1.46% and 24.77%. SO_4^{--} is the most common anion after Cl^{-}.

Therefore, the classification of anions according to their predominance is of the type: $Cl^{-} > SO_4^{--} > HCO_3^{-}$.

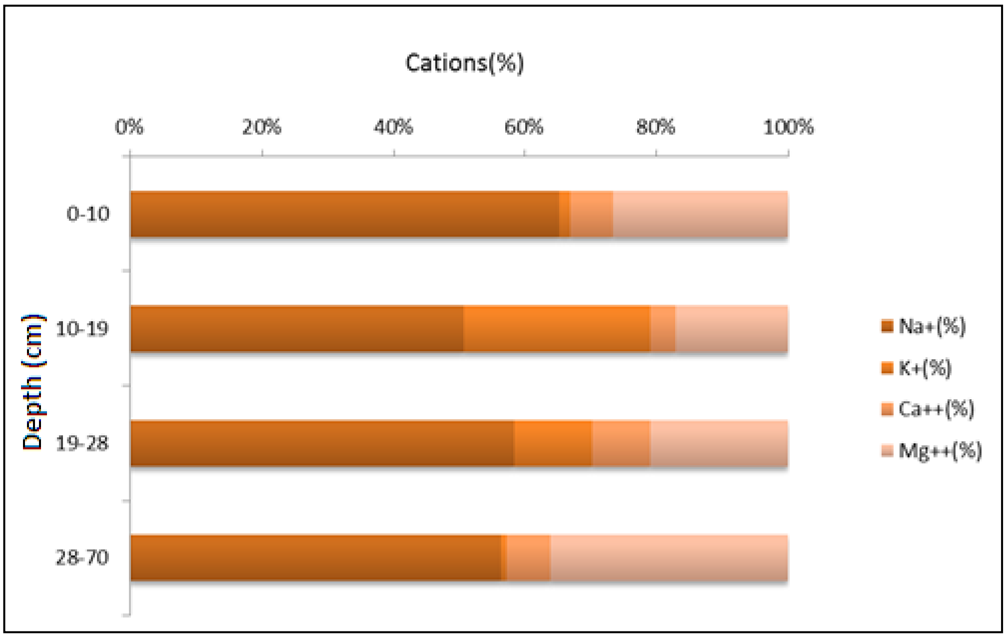

Figure 6. Distribution of cations in the soil solution of profile 2.

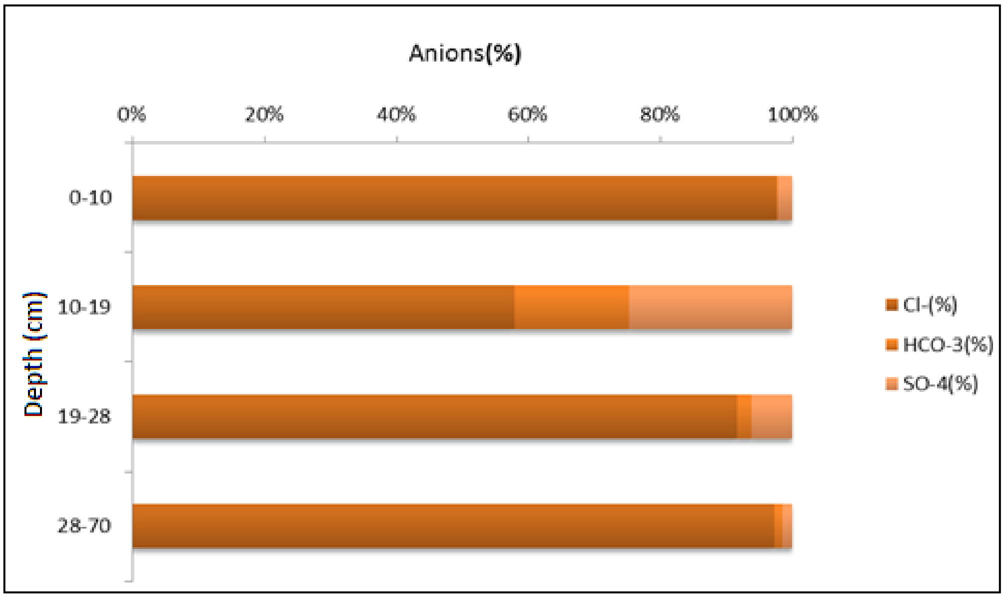

Figure 7. Distribution of anions in the soil solution of profile 2.

3.4.2.5. SAR

The SAR values vary between 8 and 31 (Table 5) throughout the profile2. These results show that profile 2 presents a risk of sodicity.

3.5. Soil Solution Analysis of Profile 3

The analytical results of the soil solution of Profile 1 are shown in Tables 8 and 9.

Table 8. Analytical characteristics of the soil solution of profile 3.

Horizons	pH	Na^+ (meq/l)	K^+ (meq/l)	Ca^{++} (meq/l)	Mg^{++} (meq/l)	Cl^- (meq/l)	HCO_3^- (meq/l)	SO_4^{--} (meq/l)	SAR
H1	6.81	20	2.14	1.52	8.58	20	5	12	8.92
H2	7.33	240.6	4.94	26.67	106.25	365	1	5	29.57
H3	7.3	250	1.95	26.67	106.25	386	6	12.4	30.75
H4	7.49	261	0.50	105.6	124.58	355	6	128.4	24.3

Table 9. Electrical conductivity of soil solution for wet and dry seasons.

Horizons	Depth (cm)	EC (dS/m)	
		Wet season	Dry season
H1	17	2.61	54.10
H2	33	36.2	64.80
H3	32	32.9	47.90
H4	33	42.2	49.20

3.5.1. Salinity

The distribution of salts as a function of depth during the wet season (table 9 and fig. 8) shows high salinity from the second horizon (EC=36.2dS/m) to the last horizon (EC=42.2dS/m).The salinity is low at the level of the surface horizon (EC=2.61dS/m). This is due to a leaching of soluble salts, which have accumulated at the level of the depth horizon, thus causing an increase in salinity. The saline profile is descending.

However, during the dry season (Table 9, Figure 8) we see that the salinity values oscillate between 47.9 dS/m and 64.8 dS/m. The middle part corresponds to a maximum salinity (EC=64.8 dS/m). These increases in salinity at the level of the sub-surface horizon would be due to a capillary rise of salts. So the saline profile is ascending.

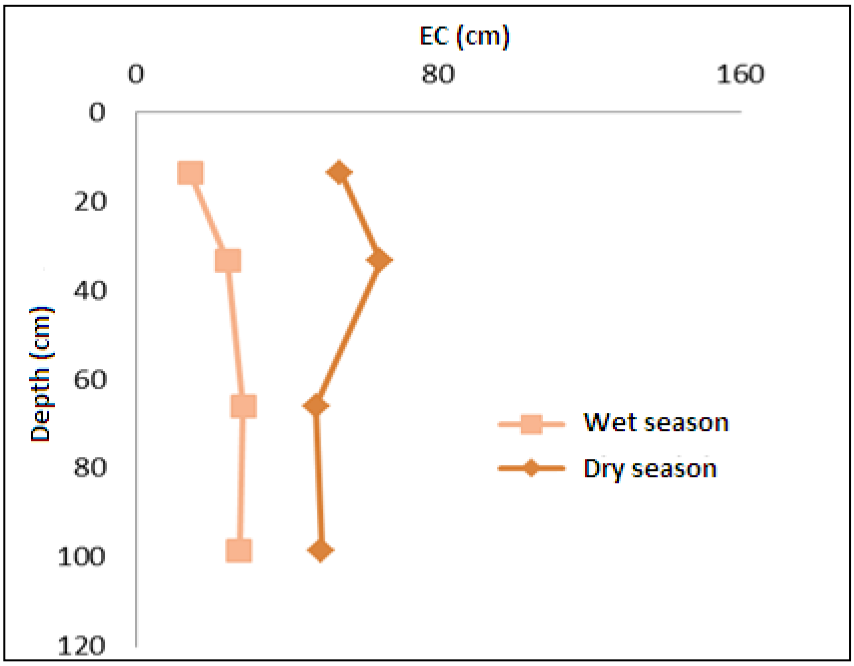

Figure 8. Salt distribution of profile 3 for wet and dry seasons.

3.5.2. pH

The pH values vary between 6.81 and 7.49 (Table 8). Generally speaking, the soil reaction is relatively alkaline.

3.5.3. Cations

Table 8 and fig. 9 show that:

- The sodium content of the soil solution is high in all horizons. It is 53.08% to 64.69%. Na^+ is the most abundant cation in profile 3.
- The potassium content of the soil solution is low throughout profile 3. It varies between 0.1% and 6.64%.
- The calcium content varies between 4.71% and 21.48% in all the horizons.

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- The magnesium content of the soil solution varies between 25.34% and 28.07% throughout profile 3. As a result, the classification of cations according to their predominance is of the type: $Na^{+} > Mg^{++} > Ca^{++} > K^{+}$.

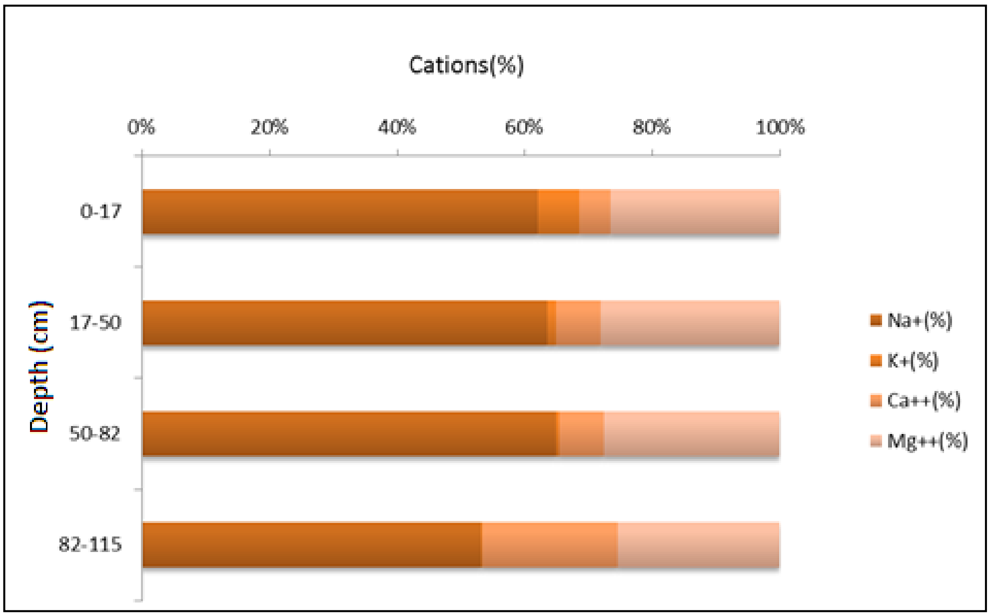

Figure 9. Distribution of cations in the soil solution of profile 3.

3.5.4. Anions

From table 8 and fig. 10 we notice:

- The chlorine contents of the soil solution of profile 3 are very high. They vary between a minimum value of 54.05% and a maximum value of 98.38%. Cl^{-} is the dominant anion in profile 3.
- The bicarbonate contents of the soil solution vary between 0.27% and 13.51%.
- The sulphate contents of the soil solution vary between 1.35% and 32.44%. SO_4^{--} is the most common anion after Cl^{-}.

Therefore, the classification of cations according to their predominance is of the type: $Cl^{-} > SO_4^{--} > HCO3^{-}$.

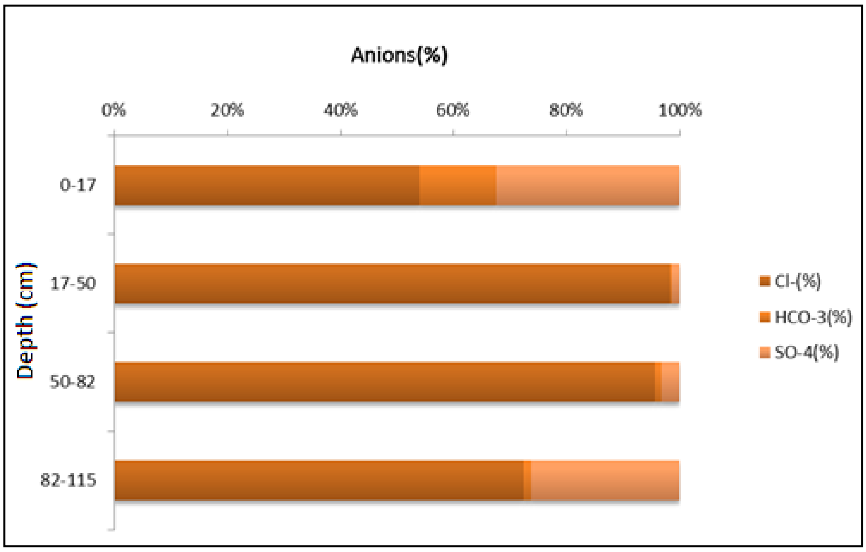

Figure 10. Distribution of anions in the soil of profile 3.

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3.5.5. SAR

The SAR values are between 8.92 and 30.75 (Table 8). We conclude that profile 3 poses a risk of sodicity.

3.6. The Chemical Facies

The Piper diagram (Fig. 11) reveals three types of soil solution chemical facies. A sodium chloride type facies for the majority of the horizons and a calcium chloride type facies for a single sample, the 5th horizon of profile1 (P1H5). The chloride facies without any particular dominance of one of the cations represents the samples P1H3, P2H1, P2H2, P2H3 and P2H5 of profile2.

These chemical facies indicate that these soils evolve according to the neutral saline pathway. This is common in North Africa [16,17,]. In Algeria, these results join those of [5] for the soils of Bas-Chéliff, [18] for the soils of Ouargla, [19] for the salty soils of Fetzara.

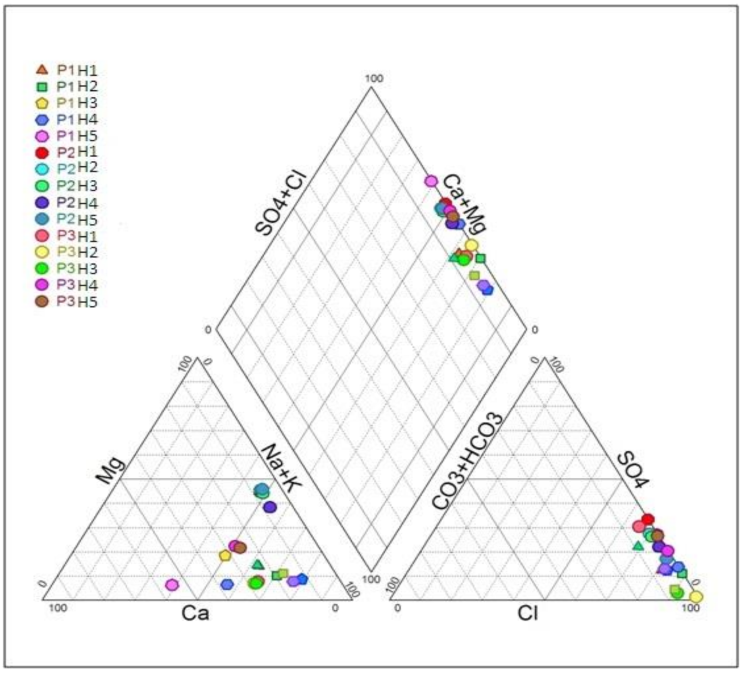

Figure 11. Chemical facies of soil solutions according to Piper diagram.

Table 10. The difference and the speed of the average salinization between the wet and dry season of the three profiles.

Profiles	The average CE(dS/m) of the profile		Gap of the EC (dS/m)between both seasons	Salinisation speed dS/m/month
	Wet season	Dry season		
1	46.02	105.31	59.29	8.47
2	22.87	82.36	59.49	8.50
3	32.04	53.75	21.71	3.10

Table 10 shows that the profiles (P1, P2, P3) show salinization between the wet and dry season. This salinity occurred at a rate which is respectively 8.47ds/m/month, 8.5 dS/m/month and 3.1 dS/m/month for profiles 1, 2 and 3. We can conclude that the three profiles underwent salinization during the dry season.

3.7. Multivariate Descriptive Statistics of the Chemical Composition of the Soil Solution

We used the principal component analysis (PCA), in order to know the elements of the soil solution which have the most weight on the variation of the EC.

3.7.1. PCA of the EC and Soil Solution Cations

According to Fig. 12 of the PCA shows that the F1 axis extracts 65.60% of the inertia from the point cloud.

On the F2 axis, the residual inertia that it extracts is 15.66%. Most of the information contained in the results is represented by the F1 and F2 axis.

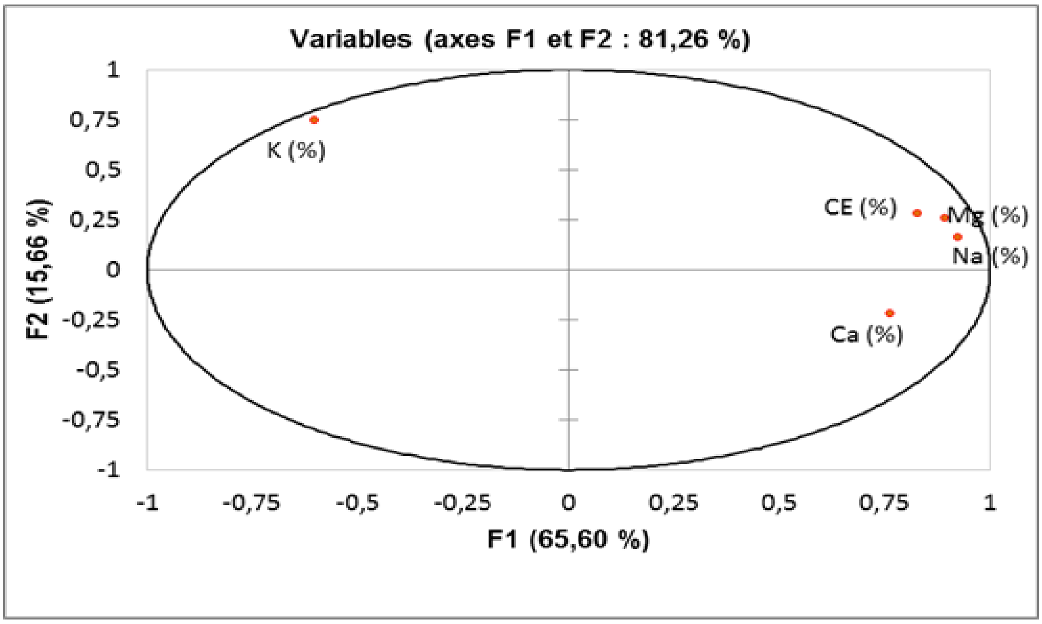

Figure 12. Principal component analysis of EC and soil solution cations.

The first axis is formed by the contribution of the variables: Na^+ (25.90%), CE (20.85%), K^+ (11.19%), Ca^{++} (17.73%) and Mg^{++} (24.30%) (Table 10). However, the F2 axis is formed by the contribution of the variables Na^+ (3.39%), CE (10.40%), K^+ (71.67%), Ca^{++} (5.91%), and Mg^{++} (8.60%). These results indicate that EC and Na^+ are close and move in the positive direction of the F1 axis, thus these two parameters are close to the correlation circle (fig. 12). We can say that Na+ has more weight (25.90%) on the EC variation, Mg^{++} comes in second position with a contribution of 24.30%. Na^+ and Mg^{++} are the soil solution cations that have the most influence on EC variation.

Table 11. Contributions of variables (%) in the formation of axes (F) .

Paramètres	F1	F2	F3	F4	F5
CE	20.85	10.4	10.49	57.88	0.35
Na^+ (%)	25.9	3.4	13.3	2.9	54.49
K^+ (%)	11.19	71.68	8.56	7.55	1.01
Ca^{++} (%)	17.73	5.91	54.85	21.41	0.08
Mg^{++} (%)	24.3	8.6	12.8	10.24	44.05

3.7.2. PCA of the EC and Soil Solution Anions

From fig. 13, the F1 axis extracts 61.4% of the inertia from the point cloud. On the F2 axis, the residual inertia that it extracts is 20.95%. Most of the information contained is represented by the axis F1 and F2.

The first axis is formed by the contribution of the variables: Cl^- (23.60%), CE (32.18%), HCO_3^- (17.81%), SO_4^{--} (26.39%), HCO_3^- (44.02%) and SO_4^{--} (12.69%) (Table 12).

The PCA revealed that HCO_3^- and Cl^- have the most influence on the EC variation compared to other anions in the soil solution. These are followed by sulfates.

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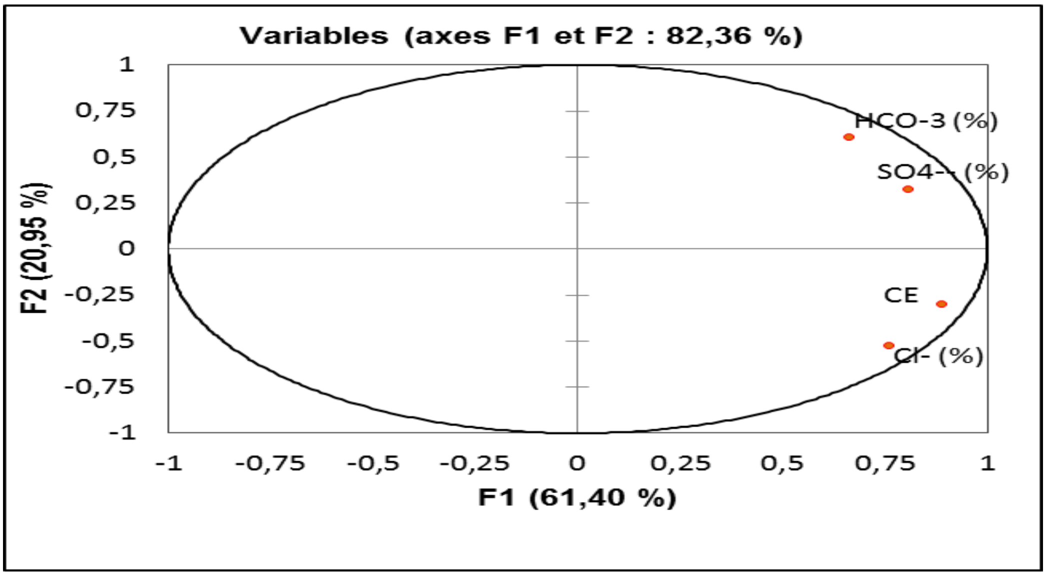

Figure 13. PCA of EC and soil solution anions.

Table 12. Contributions of variables (%) in the formation of axes.

Paramètres	F1	F2	F3	F4
EC	32.18	10.73	6.7	50.38
Cl- (%)	23.6	32.55	19.95	23.89
HCO3-(%)	17.81	44.02	34.78	3.38
SO4-- (%)	26.39	12.69	38.57	22.33

4. Discussion

The soils studied are characterized by a heavy texture (clayey to clayey-loamy) sometimes alternating with layers of silty texture. This grain size distribution demonstrates the alluvial nature of the study area. Similarly, these profiles are calcareous with rates that are around 20%.

However, the analyzes show that the three profiles are excessively salty during the wet and dry season. In addition, we observed a maximum salinity during the dry season (EC = 138dS/m) for profile 1. This is due to the presence of a saline aquifer at low depth (1.5m deep; EC= 60 dS/m) [10]. On the other hand, the evaporating climate of this region (ETP = 1500 mm/year) and the clayey texture promote the capillary rise of water from the salty aquifer during the dry season. The three profiles in question present a salinization between the wet and dry season, this salinity occurred at a rate which is respectively 8.47dS/m/month, 8.5 dS/m/month and 3.1 dS/m /month for profiles 1, 2 and 3. As a result, the saline profile is of the convex type for profile 3. The maximum salinity is observed at the level of the middle part of the profile. On the other hand, for profile 1 the distribution of salts is descending because the salts are accumulated in the lower part of the profile. This is believed to be due to capillary breakage in the lower parts of the profile, which is caused by the shrinkage slots present in the profile.

However, the very evaporating climate, combined with a relatively fine grain size, accentuates the phenomenon of salinization in the dry period. Soil salinity increases when the soil dries out [21].

The difference in variation of the salinization rate between the profiles is controlled by the grain size, the morphology (cracks) and the presence or absence of a shallow and highly mineralized water table.

. Therefore, we conclude that the movement of salts is not always upward during the dry seasons, because the saline behavior differs from one soil to another. This difference in behavior is also due to the morphological characteristics of the soils [5].

The pH of these soils is around 7.4 demonstrating a slight alkalinity of these soils. Thus, the SAR shows that the risk of alkalinization is significant. The cationic composition of the soil solution is dominated by Na+ and that of the anions is dominated by chlorides.

The principal component analysis (PCA) showed that the chemical elements of the soil solution which have the most influence on the variability of salinity are: Na+, Mg++ and HCO3-. We can explain the

result of this analysis by the fact that Na+ does not enter into the phenomena of precipitation of minerals up to very high EC values [20].
The evolution of Na^+ is explained by the fact that it is the dominant cation in the solution of the soils and that it does not enter into the phenomena of precipitation of minerals up to very high EC values [20].
The sodium chloride chemical facies indicates that these soils evolve according to the neutral saline pathway. This is common in North Africa [16,17].

Conclusion

The objective of this work is devoted to the study of the seasonal evolution of the salinity of the soils of the plain of Bas-Chéliff.
The results obtained show that the study area is characterized by a predominantly silty-clayey texture. The soils studied are generally alkaline, calcareous (18%), poor in organic matter and weakly gypsum (gypsum < 3%).
The analysis of the soil solution of the three profiles showed that chlorides and sodium constitutea predominance in the chemical composition of the solution of the soils studied. Thus these soils have a very high salinity during the dry season compared to the wet season this salinity is produced at a rate of 6.69 dS/m/month. With a maximum salinity observed at the level of profile 1 (EC=138 dS/m), the saline profiles for the dry season are descending, convex and ascending types for profile 1, 2 and 3 consecutively. The profiles in question all suffered salinization during the dry season at a rate which is respectively 8.47 dS/m/month, 8.5 dS/m/month and 3.1 dS/m/month for profiles 1, 2 and 3.
In general, soil pH values show a relatively alkaline soil reaction. The risk of alkalinization is very high with regard to the SAR values for the three profiles.
The cationic and anionic composition of the soil solution is strongly dominated by chlorides and sodium for all profiles. This explains the dominance of the chemical facies of the sodium chloride type.
On the other hand, the salinization of the soils of Bas-Cheliff is relatively heterogeneous, it can reach very high salinity levels during the dry season.
Principal component analysis (PCA) revealed that the chemical elements of the soil solution (Na^+ and Cl^-) have the most influence on the variability of salinity.
In general, the grain size composition, the topographic situation, the depth of the water table, the degree of salinity of the water table, the state of the surface of the soil and the specific morphological characteristics of each horizon play a preponderant role in the difference in behavior of the studied profiles.
Finally, in order to better understand the temporal evolution of salinity in Bas-Cheliff, it must be studied over a longer season.

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