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NATURE ENVIRONMENT AND POLLUTION TECHNOLOGY

Article In Press

PEER-REVIEWED PREPUBLISHED MANUSCRIPT

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Hassina Mahdi and Samir Hadj-Miloud

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CITE THIS ARTICLE
Mahdi, H. and Hadj-Miloud, S., 2027. Dispersive Behaviour of Saline Sodic Soils under Semi-Arid Conditions. *Nature Environment and Pollution Technology*, 26(1), D1947.

https://doi.org/10.46488/NEPT.2027.v26i01.D1947

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PUBLICATION STATUS

PEER REVIEW	ONLINE VERSION	FINAL ISSUE
Completed	**Prepublished**	**March 2027**

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Original Research

Dispersive Behaviour of Saline Sodic Soils under Semi - Arid Conditions

Hassina Mahdi[1]†, Samir Hadj-Miloud[1]

[1] Laboratory of Water Management in Agriculture (LMEA)/National Higher Agronomic School/ department of soil science/Avenue Hassan Badi El Harrach,16200, ES1603, Algiers, Algeria: h.mahdi@edu.ensa.dz
[1] Laboratory of Water Management in Agriculture (LMEA)/National Higher Agronomic School/ department of soil science/Avenue Hassan Badi El Harrach,16200, ES1603, Algiers, Algeria: samir.hadjmiloud@edu.ensa.dz
Corresponding author: Hassina Mahdi, h.mahdi@edu.ensa.dz)

Abstract

Sodicity is one of the most important problems threatening agricultural production in arid and semi-arid regions, Lower Chellif is one of these regions, where saline-sodic soils are affected by soil dispersion. This work aims to investigate the dispersive behaviour of saline-sodic soils in Lower Chellif and classify them based on measurements of their clay dispersion indices, Mechanical and Spontaneous Dispersion. The laboratory investigation used thirty-two (32) soils from the 0 - 20 cm layer in Hmadna, Lower Chellif, Algeria. After characterization of the soil solution, we calculated the Sodium Adsorption Ratio and Cations Ratio of soil Structural Stability. Water Dispersible Clay, Clay Dispersible Ratio, and Clay Flocculation Index were determined, and correlation analysis was used. Spontaneous and Mechanical Dispersion were measured, and threshold lines relating SAR and CROSS to EC were derived for both types of dispersion. They were used, in order to indicate the dispersive behaviour. The studied soils showed a variation of electrical conductivity ranging from 0.95 to 7 dS/m. Sodium was the most abundant soluble cation, while potassium was the least abundant. SAR ranged from 3.84 to 12.77 and CROSS from 4.17 to 14.18. Water Dispersible Clay ranged from 0.34 % to 1.10 %, with low but variable averages, showing a coefficient of variation of 36.68%. Clay Dispersible Ratio had a coefficient of variation of 37,42%, and Clay Flocculation Index had a coefficient of variation of about 0.44%. Spontaneous Dispersion ranged from 0.08% to 0.45%, (mean 0.22%), while Mechanical Dispersion ranged from 0.12% to 0.62%, (mean 0.34%). Mechanical Dispersion and Water Dispersible Clay had a highly significant positive correlation with EC, SAR, CROSS, K^+, Mg^{2+}, and Na^+, and a significant positive correlation with Ca^{2+}. Spontaneous Dispersion showed a significant positive correlation with EC, SAR, CROSS, K^+, Mg^{2+}, Na^+, and a significant positive correlation with Ca^{2+}. Correlation between clay dispersion indices indicated a highly significant positive correlation between Water Dispersible Clay and Mechanical Dispersion; it was also significant and positive with Spontaneous Dispersion. The resulting schemes with threshold lines classified the saline-sodic soils of Lower Chellif as potentially dispersive and Dispersive. For an EC ≤ 8 dS/m and a SAR≤ 13, the studied soils start to lose their flocculation, with more disturbance of these soils in the field, they become dispersive. Further research is needed across a wide range of salinity classes to better characterize soil dispersion and dispersive behaviour in Lower Chellif, especially with the high risk of salinisation, which has been observed in recent years, and its implications for soil productivity .

Keywords

Cation ratio of soil structural stability; Dispersive behavior; Mechanical dispersion; Sodium adsorption ratio; Spontaneous dispersion; Water dispersible clay

1. INTRODUCTION

Soil degradation by sodicity is a serious problem that affects agricultural production, especially in semi-arid and arid regions. When sodium ions are adsorbed by soil particles as exchangeable cations and excess soluble salts are leached from the soil, soils become sodic, and the soil structure is degraded by means of clay swelling and dispersion (Rengasamy 2002).

Soil dispersion is a critical factor influencing soil health and agricultural productivity (Rengasamy 2025) .Soil dispersion is one of the major processes responsible for the degradation of soil structure (Rengasamy 2002; Chorom and Rengasamy 2005; Marchuk et al. 2016). It can be caused by several factors. In fact, the partial saturation by exchangeable sodium increases dispersion of soil aggregates (Rengasamy 1991; Levey et al. 1998; Kaewmano et al 2009; Bennett et al. 2016). When EC is low and ESP lower than 15, there is dispersion (Rengasamy et al. 2016; De melo et al. 2019). Soil texture (Rengasamy and Marchuk 2011), type of clay mineral (Mc Neal and Coleman 1966; Goldberg et al. 1991; Ruiz vera and Laosheng 2006), and organic matter (OM) (Nelson et al. 1999) influence dispersion of soil aggregates. Plant root growth increased the formation of large water-stable macroaggregates (> 2000 µm), which would lower clay dispersion by reducing the exposure of clay particles to water (Velasco- Molina et al. 1971). Silt and high magnesium content may induce non-sodic soils (ESP <6%) to disperse, while organic matter, clay mineralogy, acidity, and high iron content may prevent sodic soils (ESP>6%) from dispersing (Rengasamy 2002; Hardie 2009).

In 2002, Rengasamy proposed a method to measure dispersion and classify soils into three classes: Flocculated soils, potentially dispersive soils and dispersive soils. Spontaneous dispersion concerned the deterioration of sodic clay particles when wetted above saturation, whereas mechanical dispersion needs external energy to occur (Rengasamy 2002).

Several studies have treated the question of dispersion and many indices were calculated: Mechanical dispersion, Spontaneous dispersion and dispersive potential (Rengasamy 2002), zeta potential (Chorom and Rengasamy 1995), Cation Ratio of Structural Stability (Rengasamy and Marchuk 2011), net dispersive charge (Rengasamy et al. 2016), The exchangeable dispersive percentage (Bennett et al. 2016), Clay Flocculation Index, Clay Dispersion Ratio and Water Dispersible Clay (Melo et al. 2015; Basga et al. 2018 ; Luo et al. 2024). Turbidity and Zeta potential were also used by Marchuk and Rengasamy 2011; Luo et al. 2024) for characterization of clay dispersion.

Lower Cheliff 's soils are generally affected by salinisation (Durand 1956; Douaoui 2005; Hadj Miloud 2010). This phenomenon is related to the nature of alluvium, rich in soluble salts, irrigation water quality and low water table depth (Durand 1956). These soils were widely studied. All the studies confirmed their high Na^+ concentration. K^+ and Na^+ can reduce soil hydraulic conductivity by causing clay dispersion. Because of the small hydrated ion size of these two elements, attractive forces between calcium saturated clay particles are greater than repulsive forces formed by the diffuse double layer operating along the clay's negative surface; there will be limitation of clay interlayer spacing expansion (Rengasamy et al.1984; Rengasamy 2002).

Several studies on clay dispersion specialized in pure clay particles and focused on the effects of pH and electrolyte concentration on their dispersion and zeta potential (Chorom and Rengasamy, 2005; He et al., 2013; Marchuk 2016), while others, focused on the chemical and environmental fields effects (Melo et al. 2015; Basga et al. 2018; Li et al. 2021; Hou et al. 2023).

However, knowledge about how the degree of clay dispersion in saline-sodic soils is characterized, classified, and controlled is still limited.

More data need to be collected to better understand the dispersion behaviour of saline-sodic soils, which would support a more accurate classification of these soils and ultimately contribute to improving their productivity.

The objective of this research is to investigate the dispersive behaviour of saline-sodic soils in the semi-arid conditions of Lower Chellif. We combined the clay dispersion indices for soils having an EC< 8 dS/m and the soil characteristics to classify these soils and predict their dispersive behaviour. This study provides a better understanding of structural degradation mechanisms, thereby offering a scientific basis for soil management.

2. MATERIALS AND METHODS

2.1. Location and description of the study area

The soil samples used in this study were selected from the experimental station of the National Institute of Agronomic Research of Hmadna, it belongs to Hmadna perimeter in the Lower Cheliff, Algeria., (coordinates 35° 54' N. and 0° 47' E). It is a semi-arid region,with hot dry summer and harsh winter, the average annual

rainfall is about 250 mm. Saline-sodic soil are the dominant soils and *Sueda fructuosa*, the dominant plant. The soil was sampled from the field in 32 samples points. The choice of this number is justified by the need to cover a wide range of ESP values, thus allowing a representative analysis of its influence on the soil dispersion phenomenon. Soil samples were collected from the 0 - 20 cm layer, air-dried, and sieved to 2 mm.

2.2. Soil analysis and measurements

The particle size analysis was done by the international method with Robinson pipette (ISRIC 2002). Cation Exchange Capacity (CEC) was analysed by the saturation method with ammonium acetate (Mathieu and Pieltain 2003) and the exchangeable bases were analysed as described by Jackson (1958). Measurement of Electrical Conductivity (EC) was applied by the electrical method on the soil-water ratio of 1:5 extracts (Mathieu and Pieltain 2003). The soluble cations were estimated by the atomic absorption spectrometry (ISRIC 2002). CO_3^{2-} and HCO_3^- were analysed using the double indicator-neutralization titration, Cl^- was done by silver nitrate titration and $SO_4^{2-}$was determined by the gravimetric method with barium chloride (Mathieu and Pieltain 2003). The pH analysis was done by the potentiometric method on the soil extract soil/water of 1/5. The volumetric method by the Bernard calcimeter was used for the determination of the total carbonates $CaCO_3$ (Mathieu and Pieltain 2003). The Ann method was used for the determination of OM (Aubert 1978). Experiments were conducted using triplicate samples. Mineralogical composition was determined on clay fraction (<2 mm) by X-ray diffraction (XRD).The results of soil solution analysis were used to calculate SAR and CROSS (Rengasamy and Marchuk 2011).

SAR is given by the equation (1)

$$\mathrm{SAR} = \frac{\mathrm{Na}}{\sqrt{\frac{\mathrm{Ca+Mg}}{2}}} \qquad (1)$$

Where Na^+, Ca^{+2} and Mg^{+2} are in mol_C /m^3 (mol_c /m^3 =meq /L)

CROSS (2) takes in a count the dispersive effect and power of K, which doesn't appear in the calculation of SAR. It is given by the equation 1

$$\mathrm{CROSS} = (\mathrm{Na} + 0.56\mathrm{K})/[(\mathrm{Ca}+0.6\mathrm{Mg})/2]^{0.5} \quad (1)$$

Where Na^+, Ca^{+2} and Mg^{+2} are in mol_C /m^3

Results of sodium and Cation Exchangeable Capacity were used to calculate Exchangeable Sodium Percentage (ESP) with the following equation

$$\mathrm{ESP} = \frac{\mathrm{Na}}{CEC} * 100$$

Na+ and CEC were in cmol.kg1, and ESP was in %.

Total Clay (TC) analysis and Water Dispersible Clay (WDC) were carried out using the method described by Melo et al. (2015). Their obtained results were used to calculate Clay Dispersion Ratio (CDR) and Clay Flocculation Index (CFI) as explained by Luo et al. 2024 by the equations 2 and 3.

$$\mathrm{CDR} = \frac{\mathrm{WDC}}{\mathrm{TC}} \qquad (2)$$

$$\mathrm{CFI} = \frac{\mathrm{TC-WDC}}{\mathrm{TC}} \qquad (3)$$

Where WDC and TC were in %.

2.3. DISPERSIVE BEHAVIOUR STUDY

The study of the dispersive behaviour passed by the measurement of Mechanical and Spontaneous Dispersion (MD and SD). A range of 32 saline-sodic soils from Hmadna perimeter and representative of lower Chellif was used They were carried out using the method of Rengasamy 2002. The interpretation of the dispersion test will be complete only when the composition of the equilibrium soil solution is known (Rengasamy 2002). The equilibrium solutions from the Spontaneous and Mechanical Dispersion were then separated from their respective soil suspensions. pH and EC were measured and the cations Ca^{2+}, Mg^{2+}, K^+ and Na^+ in the supernatant were estimated by atomic absorption spectrometry (Rengasamy 2002).

The obtained results were used to calculate SAR and CROSS.. For each sample, SAR and EC values were abtained and reported on the graph for both Spontaneous and Mechanical Dispersion (Fig. 2 and 3). Then CROSSS and EC values were abtained and reported on the graph for both Spontaneous and Mechanical Dispersion.

As explained by Rengasamy 1984 2002, threshold lines relating SAR and EC for Spontaneous and Mechanical Dispersion and CROSS and EC for Spontaneous and Mechanical Dispersion too. Thus, a scheme of the prediction of dispersive behaviour of saline - sodic soil was obtained. Each class is defined on the basis of predictive established relationships. Three classes of dispersion are identified

Dispersive Soils (Class1): Soils which disperse spontaneously and which have an EC less than predicted by the threshold line

Potentially Dispersive soils (class 2): Soils which disperse after mechanical shaking and have an EC less than predicted by the appropriate threshold line

Flocculated Soils (Class 3): When soils have more than the minimum electrolyte level required for flocculation as defined by the appropriate threshold line.

2.4. STATISTICAL ANALYSIS

The organization of data, the descriptive statistics and the correlation analysis were done by Microsoft Excel 2016.

3. RESULTS

3.1. Soil characteristics

Table 1 summarizes the results of the descriptive statistics of soil characteristics. Soils are characterized by variable electrical conductivity. It is ranging from 0.95 to 7 dS/m. The results of soluble cations analysis indicates that, of the four major cations, sodium was the most abundant, reaching 38.97 mol_c/m^3 .The potassium was the last one with a maximum of 0.95 mol_c/m^3, with a difference of 0.87 mol_c/m^3 between the minimum and the maximum.Ca^{+2} ranged from 1.88 mol_c/m^3 to 13.62 mol_c/m^3 whereas Mg^{+2} ranged from 0.91mol_c/m^3 to 7.79 mol_c/m^3.The pH values ranged from 7.91 to, 8.30 thus showing a small variation (CV = 0.97) alkalinity of the soil reaction.HCO_3^- ranged from 0,10 to 1.32 mol_c/m^3, SO_4^{2-} ranged from 5.87 mol_c/m^3 to 31.85 mol_c/m^3, and Cl^- ranged from 12 mol_c/m^3 to 36 mol_c/m^3. The differences were large for SO_4^{2-} (25.98 mol_c/m^3) and Cl^- (24 mol_c/m^3) and small in the for HCO_3^- (1.22 mol_c/m^3).

Na^+_{ex} ranged from 2.58 cmol/kg to 8.47 cmol/kg, with a variation of 31.43 %, CEC ranged from 24.25 to 26.73 cmol/kg, with a smaller variation than Na^+_{ex} (2.88%). The sodicity indicator ESP, had large differences, it ranged from 9.68% to 32.94%, with a large variation. Whereas SAR, and CROSS ranged from 3.84 to 12.77 and from 4.17 to 14.18, presenting the coefficients of variation of 35.34% and 36.90%, respectively. Calcium carbonate content ranged from 14.62% to 19.06% with a small coefficient of variation (6.58%). The soil organic carbon content is low overall. It ranged from 1.55% and 2.47%.

The clay fraction was constituted mainly by kaolinite, chlorite, illite, interstratified illite/smectite and montmorillonite of 14 A°, with a degraded structure and bad crystalized.

3.2. Soil dispersion

The observation of table 2 and fig 1 indicates that SD ranged from 0.08% to 0.45%, the mean was 0.22%, a significant difference. MD varied from 0.12% to 0.62%, with a mean of 0.34%, thus a significant difference, WDC values were between 0.34% and 1.10%, thus a mean of 0.60%, significant difference. For TC, the difference was non-significant because of the variation of values between 44.40% and 55.02% and the mean of 52.85%,. CFI ranged from 0.98% to 0.99%, CDR varied between 0.01 and 0.02 %. These four characteristics SD, MD, CDW and CDR present coefficients of variation that exceed 36 %. These clay indices variabilities indicate a remarquable variation of soil dispersion of Lower Chellif saline-sodic soils

Table 1: Studied soil characteristics

Soil characteristics	Mean	Max	Min	CV (%)	Med	Standard deviation
EC (dS/m)	3.37	7.00	0.95	49.86	3.23	1.68
Ca^{+2}(mol_c /m^3)	9.28	13.62	1.88	34.94	10.79	3.24
Mg^{+2}(mol_c /m^3)	3.72	7.79	0.91	51.50	3.63	1.91
Na^{+}(mol_c /m^3)	18.59	38.97	4.53	51.50	18.14	9.57
K^{+}(mol_c /m^3)	0.46	0.95	0.12	51.55	0.43	0.23
pH	8.10	8.30	7.91	0.97	8.10	0.07
HCO_3^{-}(mol_c /m^3)	0.79	1.32	0.10	43.39	0.80	0.34
SO_4^{2-}(mol_c /m^3)	22.64	31.85	5.87	32.58	27.47	7.37
Cl^{-} (mol_c /m^3)	20.91	36.00	12.00	28.60	21.00	5.98
SAR	7.06	12.77	3.84	35.34	6.63	2.49
CROSS	7.63	14.18	4.17	36.90	7.07	2.81
ESP	24.63	32.94	9.68	30.58	28.52	7.53
Na^{+}_{ex} (cmol/kg)	6.30	8.47	2.58	31.43	7.39	1.98
CEC (cmol/kg)	25.50	26.73	24.25	2.88	25.80	0.73
$CaCO_3$ (%)	16.88	19.06	14.62	6.58	16.89	1.11
OM (%)	2.16	2.47	1.55	12.01	2.17	0.26

Table 2: Studied soil dispersion characteristics

Soil characteristics	Mean	Max	Min	CV (%)	Med	Standard deviation
SD (%)	0.22	0.45	0.08	45.57	0.19	0.10
MD (%)	0.34	0.62	0.12	37.00	0.33	0.13
TC (%)	52.15	55.02	44.40	4.58	52.53	2.39
WDC (%)	0.60	1.10	0.34	36.68	0.55	0.22
CDR	0.012	0.022	0.006	37.427	0.011	0.004
CFI	0.988	0.994	0.978	0.439	0.989	0.004

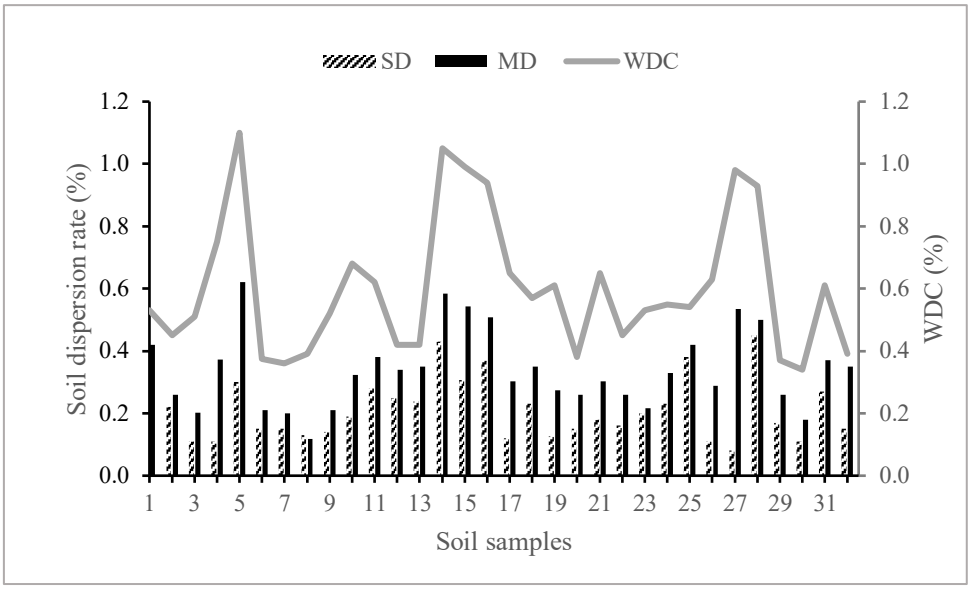


Fig. 1: Evolution of SD, MD for the 32 studied soil samples of Lower Chellif

3.3. The dispersive behaviour of saline sodic soils

All the studied soil disperse spontaneously. Simple linear regression showed that the relationship between EC and SAR was strong (fig 2 and 3) ($R^2 = 0.74$ $p < 0.05$).; The obtained threshold line was

$\mathrm{EC} = 0.30\ \mathrm{SAR} - 0.22$ EC is in dS/m for Spontaneous Dispersion

This R^2 became higher 0.90 $p < 0.05$ After shaking, indicating a very strong relations between EC and SAR. The obtained threshold line was

$\mathrm{EC} = 0.53\ \mathrm{SAR} - 0.98$ EC is in dS/m for Spontaneous Dispersion

The comparison between the EC predicted values, from the MD threshold lines and the EC measured values from the experiment showed that 13 soil samples present an EC lower than the predicted one, hence considered as potentially dispersive.19 soil samples had a measured EC lower than the predicted one on SD threshold lines, hence considered as Dispersive soils.

When we have used CROSS, the obtained threshold lines were

$\mathrm{EC} = 0.16\ \mathrm{CROSS} + 0{,}21$ EC is in dS/m for Mechanical Dispersion

$\mathrm{EC} = 0.48\ \mathrm{CROSS} - 1$ EC is in dS/m for Spontaneous Dispersion

The use of CROSS gives a higher and stronger correlation: $R^2 = 0.76$ $p < 0.05$ for Spontaneous Dispersion and $R^2 = 0.93$ $p < 0.05$ for Mechanical Dispersion. The comparison between the EC predicted values, from the MD threshold lines and the EC measured values from the experiment showed that 13 soil samples present an EC lower than the predicted one, hence considered as potentially dispersive. It appears from the results that SAR and gave the same number of potentially dispersive soils, the difference is that the correlation for CROSS is stronger than SAR.

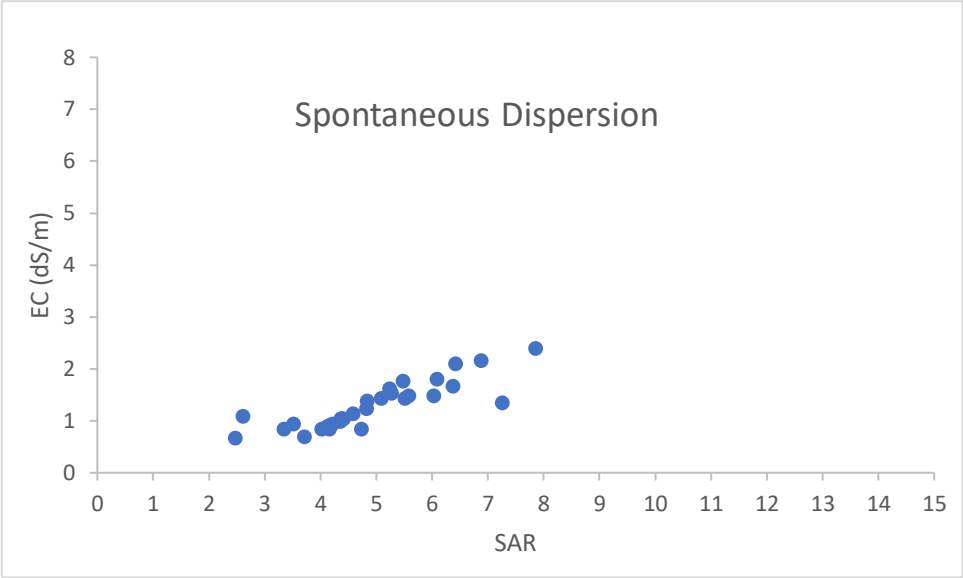


Fig. 2: Relationship between EC and SAR in case of Spontaneous Dispersion

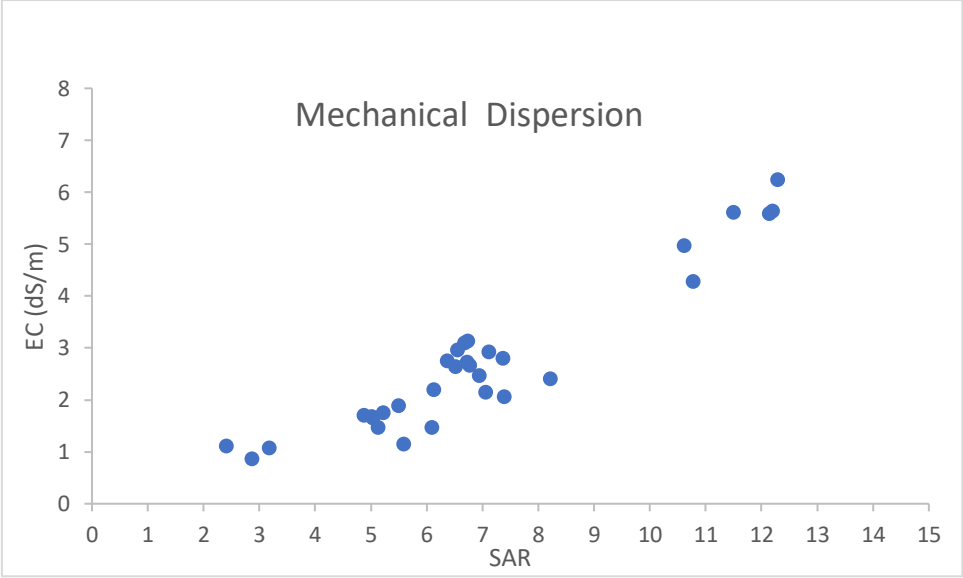


Fig. 3: Relationship between EC and SAR in case of Mechanical Dispersion

Thus, the two threshold obtained lines for both Spontaneous and Mechanical Dispersion were used to have the scheme of Dispersive Behaviour (Fig 4)

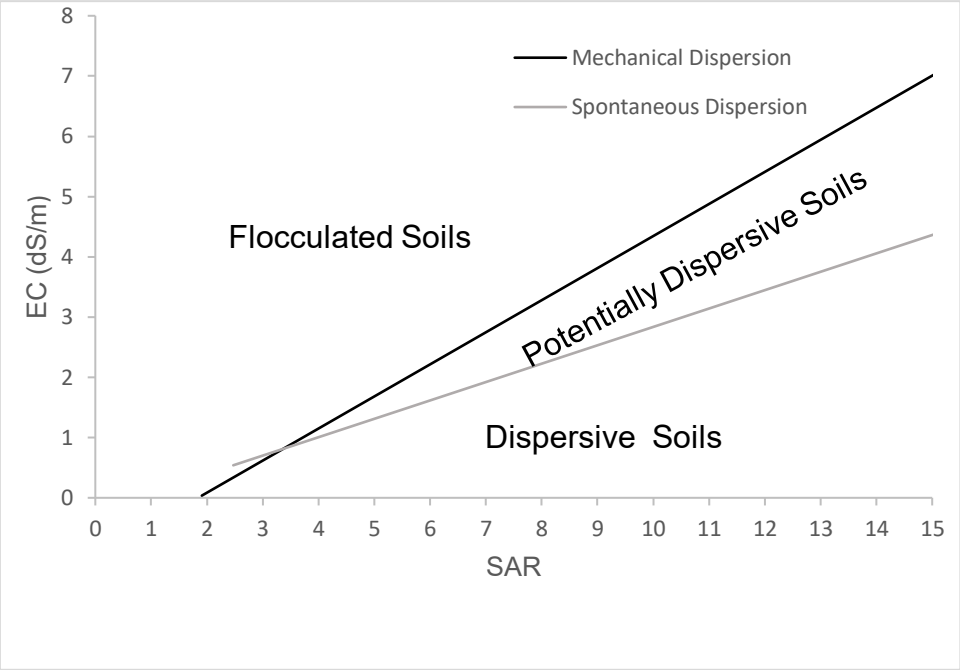


Fig. 4: Scheme of prediction of dispersive behaviour of saline sodic soil as related to EC and SAR

3.4. Correlation analysis between soil solution parameters of saline sodic soils and clay dispersion indices

A correlation matrix was conducted to study the relationship between soil solution parameters and clay dispersion indices used in the previous scheme. The results (table 3) showed that correlations between MD, WDC and EC, SAR, CROSS, K^+, Mg^{2+}, Na^+ were high, positive and significant (p<0.01). They were positive and significant with Ca^{2+} (p<0.05). The correlation between SD and EC, SAR, CROSS, K^+, $Mg^{2+,}$ Na^+ was positive and significant (p<0.01), it was positive and significant with Ca^{2+}. (p<0.05).

A high positive and significant correlation was observed between WDC and MD (p<0.01), and a high positive and significant one with SD (p<0.01).

We can conclude that there is a close relation between soil solution parameters and the studied indices, thus SD, MD and WDC can be used to characterize the soil dispersion. These results were also confirmed by Basga et al. (2018) and Luo et al, (2024). The coefficient of correlation of potassium was important with 0.84 for WDC and 0.79 for MD despite its lowest average of 0.46 mol_c /m^3 (table 1). SAR and CROSS present the same coefficients for the three clay dispersion indices.

Table 3: Matrix of correlation relating soil solution parameters of studied soils and clay dispersion indices;

	WDC	SD	MD
WDC	1.00		
SD	0.47*	1.00	
MD	0.86*	0.68**	1.00
EC	**0.84***	0.56*	**0.81***
SAR	**0.84***	0.55*	**0.80***
CROSS	**0.84***	0.55*	**0.80***
Ca^{+2}	**0.42****	0.27**	**0.40****
Mg^{+2}	**0.83***	0.54*	**0.79***
Na^{+}	**0.83***	0.54*	**0.79***
K^{+}	**0.84***	0.55*	**0.79**

* $p<0.01$, **($p<0.05$)

4. DISCUSSION

4.1. Variability of salinity and sodicity: interpretation and implication

The studied soils have a variable EC, from 0,95 to 7 ds/m, they cover three from five classes of salinity determined by USSL (1954): non saline (0-2) ds/m, sightly saline (2- 4) ds/m and moderately saline (4-8) ds/m.Their sodicity indicator (ESP) is variable and cover three from five classes determined by FAO (1984): < 5 low sodicity, (5-20) moderate sodicity and (20-45) severe sodicity. SAR is ranging from 3.84 to 12.77 indicating the risk of alkalinity and cover two from four classes determined by USSL (1954): (SAR < 10) low risk, (10 < SAR <18) medium risk SAR > 18 high risk, and SAR > 26 very high risk

Na^{+} was found to be the most abundant element. these results are perfectly consistent with those obtained by (Saidi 2004; Douaoui 2005; Hadj-Miloud 2010, Hadj-Miloud, 2019; Ouamer 2023).

The large variabilities of EC, ESP and SAR large of the studied soils translates the geochemical heterogeneity of Lower Chellif soils, influenced by the nature of alluvium and water irrigation. This saline - sodic environment is explained by simultaneous processes of salinisation, desalinization, and improvement increasing Na levels especially where the ground water is closer to soil surface, Contrary to the very aridic regions, where sodicity is related to the progressive concentration of salt (Durand 1956) . This sodicity is also related to the use of irrigation water rich in Na^{+} and Cl^{-} (Durand 1956; Hadj-Miloud 2019).

4.2. High clay particle percentage, factor that enhance soil dispersion

The soil texture for the thirty-two samples was dominated by clay with average of 52.15%, these soil conditions have created a suitable atmosphere for soil dispersion. Especially because of its richness of smectites; which present the property of swelling and big affinity to Na^{+}Differences studies chose that higher the soil is rich in montmorillonite, greater is the risk of soil dispersion (McNeal et al. 1968; Sumner 1993; Saejiew et al., 2004 Kaewmano et al. 2009)

4.3. Performance of SD, MD and WDC in explication of soil dispersion

SD, MD and WDC values were low (means of 0.22, 0.34 and 0.60 respectively) but variable indicating the effect of the variation of soil physicochemical properties. This closely relation was confirmed by the obtained correlations highly significative between the soil solution parameters and clay dispersion indices specially EC, SAR, CROSS, K, Mg $^{2+,}$ Na^+, Ca^{2+}. Earlier researches showed that soil dispersion depended on several soil characteristics as EC, SAR, CROSS, EC, K^+ and OM (Gupta 1984; Goldberg et al. 1988; Rengasamy et Marchuk 2011; Benett 2016; Chairunnisya et al. 2021; Khaled 2023; Luo et al. 2024). Correlations between soil solution parameters and clay dispersion indices were positive and significant, this result coincide with those obtained by Chairunnisya et al. (2021) and Luo et al. (2024).

For further investigation, a linear relationship between clay dispersion indices and soil physicochemical parameters was attempted: Multivariate linear regression models were constructed with the clay dispersion indice WDC considered as dependent variable and the chosen physicochemical properties as independent variables. Our choise focuse on the properties that have a highly significant correlation (p<0.01) with WDC and EC, SAR, CROSS, K^+, Mg $^{2+,}$ Na^+ .Cl^- were correlated positively, HCO_3^-, pH were correlated negatively. The results (table 3) show that each regression model was statistically significant. The highest coefficient of determination of soil physicochemical parameters to clay dispersion indices was 0,851 corresponding to the model relating WDC to EC, SAR, HCO_3^- , Cl^- (Table 4)

Table 4. Proposed linear regression models for prediction of WDC

Linear regression model	R^2	F	P value
WDC = 0,07 **EC** + 0,02 **SAR** + 0,17	0,840	34,90	<0,01
WDC = 0,06 **EC** + 0,29 $\mathbf{K^+}$ + 0,23	0,841	35,23	<0,01
WDC = 0,12 **EC** + 0,03 **SAR** + 0,30 $\mathbf{HCO_3^-}$ + 0,0008 $\mathbf{Cl^-}$ - 0 ,30	0,842	16,52	<0,01
WDC = 0,04 EC + 0,03 CROSS + 0,15	0,843	35,67	<0,01
WDC = 0,10 **EC** + 0,04 **CROSS**+0,30 $\mathbf{HCO_3^-}$ + 0, 001 $\mathbf{Cl^-}$ - 0 ,32	0,845	16,89	<0,01
WDC = - 0,07 **EC** + 0,09 **SAR**+0,31 $\mathbf{HCO_3^-}$ - 0, 005 $\mathbf{Cl^-}$ + 0,77 $\mathbf{K^+}$ - 0 ,41	0,851	13,66	<0,01

4.4. Remarquable k+ effect on soil dispersion

K^+ is the highest positively significative correlated characteristic despite its last lowest average. This constitutes an important indication about its role in soil dispersion. K^+ can cause dispersion of soil even if it's oresent in relatively small amount (Marchuk 2016) This dispersive effect can be explained by its hydrated radius and its big capacity to penetrate between the clay particles and destabilize them and this is similar to the funding of Marchuk and Rengasamy 2011; Marchuk and Rengasamy 2012 and Oster et al 2016 about the dispersive power of K^+.This result constitutes an original conclusion for the soils of Lower Chellif especially and the Mediterranean soils; which have never been studied under this angle of the effect of potassium.

4.5. Relation between soil solution parameters and clay dispersion

The observation of the correlation matrix (table3) let as stated that Soil solutions parameters have a high explanatory rate for soil dispersion and EC, Na^+, $K^{+,}$ SAR, CROSS, Mg^{2+}, Ca^{2+} are significant predictive variables of SD, MD and WDC. These indices are under a compound effect of the studied parameters (table4).The parameters that affect clay dispersion are mainly Potassium and sodium even if K^+ rate is low comparatively to sodium rate. The effect of aggregation and mineralogy of clay particles play an important role too.

4.6. Classification of soil in the basis of dispersive behavior

For an EC ≤ 8 dS/m and a SAR≤ 13,the studied soils They were classified as potentially dispersive (40%) and dispersive (60%), Their measured EC were less than the predicted ones fro, the threshold line. This result indicates that more disturbance of these soils on the field, can create greater dispersive soil dispersive.This was confirmed on the field where we have observed that the places disturbed mechanically look dispersed more than the ones which were never disturbed. A such situation constitutes a serious problem which must be taken in consideration especially with the mechanic disturbance.

The obtained results confirm the possibility of classification scheme for saline sodic soils like other types of soils classified by Rengasamy in 2002.This classification constitutes a suitable method good tool for a better knowledge and characterizing of the dispersion of saline sodic soils.

More indices need like zeta potential, turbidity, dispersive potential to be developed for a better knowledge and then rehabilitation of these soils

5.CONCLUSIONS

The studied saline sodic soil of lower Chellif showed a low variable SD, MD and WDC. EC was varying from 0.95 to 7 dS/m, ESP from 9.68 to 32.94 and SAR between 3.84 and 12.77. These properties constituted an appropriate atmosphere for variation of clay dispersion, well characterized by the indices SD, MD and WDC.

The obtained values of clay dispersion indices were low but variable because of their dependence of soil solution parameters. The significative correlations obtained between SD, MD, WDC and soil physicochemical parameters confirm that and allowed us to use the classification scheme to predict the dispersive behaviour of the studied soils. EC-CROSS correlation was higher than EC-SAR one but the two threshold lines determinate the same percentage of potentially Dispersive Soils.

The overall fundings emphasize the effect of Na+ and K+, thus confirming their importance in the mechanism of soil dispersion and confirming the knowledge about the interactions ion-clay in the saline sodic soils.

The saline sodic soils of lower Chellif presenting an EC ≤ 8 dS/m, a SAR≤ 13 and a CROSS ≤ 14 can be classified as Potentially Dispersive Soils and Dispersive Soils, confirming their dispersion after mechanical shaking.

Beyond the Lower Chellif region, this study has relevance for arid and semi-arid areas worldwide affected by soil salinization and sodification. The identified EC, SAR, and CROSS thresholds provide useful indicators for assessing the risk of soil dispersion and structural degradation. In the context of climate change and the expansion of irrigated agriculture, these findings may contribute to the development of sustainable soil management tools and the preservation of agricultural productivity in salt-affected soils.

Further researches need to be completed for a larger class of salinity and indices of clay dispersion for a better characterisation of soil dispersion in lower Chellif especially with the important risk of salinisation and its implication on soil productivity of these soils which is observed in these recent years.

This study constitutes a tool for a better knowledge and comprehension and evaluation of soil dispersion.

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7. BACKGROUND INFORMATION

Authors contributions : Conceptualization, H.M.; methodology, H.M.; software, H.M. and S.H.; validation, H.M. and S.H.; format analysis, H.M.; investigation, H.M.; ressources, H.M.; data curation, H.M.; Writing – original draft preparation, H.M.; writing—review and editing, H.M. and S.H.; Visualization, H.M. and S.H.; supervision, S.H. All authors have read and agreed to the published version of the manuscript.

Conflicts of interest: The authors declare no conflicts of interest: