



Research Article

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Evaluation of Soil Physical and Chemical Properties in the Fetzara Basin-Annaba (Northeast Algeria)

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ABSTRACT

The main objective of this study was to evaluate soil properties of Fetzara lake that are very affected by the phenomenon of salinization and to study their variation with depth. The total of 20 soil samples was collected from different plots at 0-30 cm in depth and were analysed in the laboratory. The soil samples were analyzed for various physico-chemical properties viz., organic carbon (C), total Nitrogen (N), cation exchangeable (Na^+ , Ca^{+2} , Mg^{+2} , K^+), pH, electrical conductivity (EC), cation exchange capacity (CEC), clay, sand and silt content, using standard laboratory procedures. The electrical conductivity of soil is characterized by a very wide variation (700-3600 $\mu\text{S}/\text{cm}$), the soil salinity has reached its maximum in the north-east and south of the lake. The result shows that the soil of Fetzara basin is predominated by sandy clay type. The pH was neutral to moderately alkaline with low to high in organic carbon and low to medium in CEC. Contents of individual exchangeable cations could be lined up in a following decreasing sequence: $\text{Ca}^{+2} > \text{Mg}^{+2} > \text{Na}^+ > \text{K}^+$.

Keywords: Fetzara; Soil; Salinization; Cation exchangeable; Organic carbon; Total Nitrogen

INTRODUCTION

The suitability of soil for plant growth depends heavily on its structural properties and the nutrient concentration of the soil solution [1]. Soil properties are divided into physical, chemical and biological properties. Physical properties of the soil include soil texture, infiltration rate, and soil structure. Organic matter, cation and anion exchange capacity, pH, level of nitrogen, and carbonate are some of the important chemical properties of the soil [2]. Soil chemical elements have a spatial variability, especially in agricultural areas [3]. Biological properties refer to the living component, which consists of micro-organisms (such as microbes, fungi), macro-organisms (isopods and earthworms) and plant roots [4,5].

Soil physical properties influence the soil chemistry also determines its corrosivity, stability, and ability to absorb pollutants and to filter water. It is the surface chemistry of clays and humus colloids that determines soil's chemical properties. Indicators of soil chemical properties determining of the soil quality included soil organic material (organic C), the pH of the soil, Cation Exchange Capacity (CEC), total Nitrogen (N) and cations Exchangeable (Na^+ , Ca^{+2} , Mg^{+2} , K^+). Basically, the soil nutrients can be divided by two categories namely organic and inorganic matters. Organic matter is a matter composed by waste of living organisms such as plants and animals in the environment; whereas inorganic matter is the natural components of the soil that are naturally composed from geological system. The total of organic matters in the soil is very important as indicators of soil fertility. Where, the fertility of soil related with its capacity to store, retain and release the nutrients that are required for plant growth especially C and N [6]. The C/N ratio is an indicator of biological activity of soil [7].

Saline soils occupy over 7% of the total earth's land surface and 70% of all agricultural soils worldwide [8]. In Algeria, about 2 991 013 ha lands exhibit low to high saline levels [9]. The soils of Fetzara Lake have been the subject of several studies for agricultural development, all of which revealed any significant constraints on their use such as salinization and hydromorphy [10-13]. The objective of this study was to describe the variability of some physical and chemical soil properties.

MATERIALS AND METHODS

Study Area

The Fetzara Basin is located in Annaba Province in the northeastern part of Algeria. The peripheral area of Lake Fetzara is 24000 ha. Fetzara Lake is located at 18 km southeast of the city of Annaba in the extreme east of Algeria. It lies on 17 km from east to west and 13 km from north to south. The basin is bordered in the north by the Edough Massif, in the south by the mountains of Ain Berda, in the west by the valley of the wadi Kébir and in the east by the sandy cord of El-kantara. The geology of the area is characterized by a metamorphic core complex of Precambrian to Palaeozoic age (the Edough Massif), overlain by a sedimentary cover mainly of Mesozoic to Quaternary formations. This area is subject to a Mediterranean climate with two distinct seasons: one humid and another dry (Figure 1).

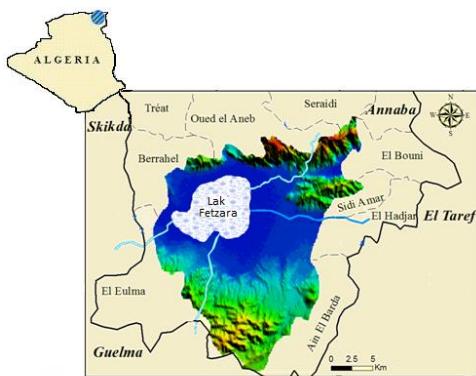


Figure 1: Location of the study area in Algerian Northeast

Soil Sampling and Laboratory Analysis

Sampling was done in the end of February 2017. 20 topsoil samples (0-30) were collected using a Gouge auger and mixed to obtain composite soil samples. The soil properties measured were texture, organic matter, pH, available phosphorous, available nitrogen, Electrical Conductivity (EC), exchangeable Ca^{+2} , Mg^{+2} , Na^+ and K^+ . Soil pH was measured using glass electrode pH meter in distilled water using a soil to water ratio of 1:2.5. Electrical conductivity meter was used to measure the EC of 1:5 soil water suspensions. Organic carbon content was determined using acid dichromate method [14]. Pipette method [15] was used to determine soil texture and the CEC was determined according to the method described in rich (1961) [16]. Available phosphorous was determined by Olsen method [17]. Exchangeable cations were extracted by ammonium acetate method and determined by flame photometry (K^+ and Na^+) [18] and atomic absorption spectroscopy (Ca^{+2} and Mg^{+2}) [19]. Total nitrogen was determined with Kjeldahl method. Soil organic carbon was analyzed according to the Walkley and Black method as described by Nelson and Sommers (1996) [14]. The organic matter (OM) content was calculated by multiplying the determined organic carbon by 1.724. Descriptive statistics of the analyzed soil data viz, minimum, maximum, mean, standard deviation, coefficient of variation and coefficient of correlation were determined using XLSTAT (Figure 2).

RESULTS

Data were subjected to descriptive analysis. The minimum, maximum, mean, standard deviations (SD), coefficient of variation (CV) for each soil property were computed for data analysis. Exploratory analyses were carried out for identification of outliers. The non-normally distributed soil properties were transformed using appropriate methods and then fit to approximate normal distribution. Pearson's correlation coefficients were determined at each case to study the relationship among the estimated soil properties.

The descriptive statistics of the soil fertility parameters are presented in Table 1. The variability was interpreted using the coefficient of variation (CV). The criteria proposed by Wilding (1985) [20] was used to classify the

parameters into most ($CV > 35\%$), moderate ($CV: 15-35\%$) and least ($CV < 15\%$) variable classes. Accordingly, EC, sand, OM, CEC, Na^+ , Mg^{+2} , K^+ were the most variability. Clay, silt, N, Ca^{+2} were the moderately variable and pH was least variable.

The results of the descriptive statistics (Table 1) revealed that the values of soil EC across the experimental field varied between 700 and 3600 $\mu\text{S}/\text{cm}$ and the values of soil pH varied between 7.4 and 8.28. As per the standards of soil EC and pH scales [21], the field soil was characterized as saline and moderately alkaline soil. The soil pH showed a very low variability across the experimental field, as indicated by the very low value of CV of 2.759%. However, most variability of EC was observed across the experimental field with a CV value of 46.537%. Soil texture is one of the most important properties that influence most of the soil functions such as cation exchange, nutrients and water retention [22,23]. The results revealed that sand was the dominant soil texture component in the experimental field (37.500%), followed by clay (31.800%) and silt (30.100%). The clay, silt and sand contents of the Fetzara Lake ranged from 15-35%, 15-47.2% and 12-65% respectively. As indicated by the values of the coefficient of variation (CV), it was observed that the spatial variability of the clay component across the experimental field was the highest (CV of 32.289%) compared to silt (CV of 34.742%) and sand (CV of 37.355%). Organic carbon varied from medium to high in the study area. A total of 65% area was medium (4-10%), and 35% area were high (10-20%). The low OC status of these soils is due to erosion of topsoil and rate of organic matter. Available nitrogen was deficient in most of the areas with values. The acute deficiency of nitrogen is due to low OC content, increased rate of mineralization and insufficient application of N fertilizer to nutrient exhaustive crops. Moreover, N deficiency was also aggravated by high OC content of the soils. The correlation between the estimated properties (Table 2 and Table 3) showed that N was significantly correlated with OC ($r=0.869$), organic matter ($r=0.841$) indicating the influence of OC and OM on nitrogen availability.

Soil C/N ratio is a sensitive indicator of soil quality. Soil C/N ratio is often considered as a sign of soil nitrogen mineralization capacity. High soil C/N ratio can slow down the decomposition rate of organic matter and organic nitrogen by limiting the soil microbial activity ability, whereas low soil C/N ratio could accelerate the process [24]. The ratio of total organic carbon and total nitrogen is the traditional guide to the nature of the organic matter present in the soil. The passive fraction of the OM can have a C/N ratio that is medium. Consequently, medium C/N ratio soils can have a wide variation in mineralisable N status. A ratio of 10-12 is normal for an arable soil with a good rate of organic matter decomposition; 15-20 indicates slow decomposition of the organic matter. Ratios greater than 25 suggest that the organic matter is not decomposing. The C/N value of the soils varied between 0.54-13.26 of the soils surface horizon (0-30 cm).

Cation exchange capacity (CEC) is the total capacity of a soil to hold exchangeable cations. Soil with high CEC indicated that the soil has a high ability to provide cations nutrient such as K^+ , Ca^{+2} and Mg^{+2} for plants [25]. The larger the value of the CEC, the higher the soil's capacity for cation nutrients. The value of CEC in the horizon (0-30 cm) of different soils varied from 7.5 to 31.8 meq/100 g with an average of 17.990 meq/100 g, which means the soils were silty or clay with medium to low organic matter level.

The cations potassium (K^+), calcium (Ca^{+2}), magnesium (Mg^{+2}) and sodium (Na^+) are an important group of nutrients essential for plant growth. Calcium is the dominant cation (Ca^{+2}) held on the cation exchange capacity of soil clay and organic matter because it is held more tightly than magnesium (Mg^{+2}) or potassium (K^+), and other exchangeable cations. The base cations can be lined up in the following sequence: $\text{Ca}^{+2} > \text{Na}^+ > \text{K}^+ > \text{Mg}^{+2}$. In the surface layer (0-30 cm) there was a significantly higher level of all cations. Generally, the greatest accumulation of organic matter in soil leads to changes in the dynamics of macro and microelements, decreases soil acidity, maintains the predominance of cationic exchange capacity and improves microbial activity [26].

The correlation coefficient results are shown in Table 3. Soil clay was positively correlated with CEC, Ca^{+2} and Mg^{+2} and negatively with sand. Silt was negatively correlated with sand and soil sand was negatively correlated with Ca^{+2} and Mg^{+2} .

Soil OC content was positively and significantly correlated with OM and N in all soil. This indicated that higher OC led to higher N and higher content of OM. The soil OM is considered as key factor driving most of the soil properties which subsequently influence nutrient storage and availability to plants [27]. Soil CEC content was also positively and significantly correlated with exchangeable cations like K^+ , Mg^{+2} and Ca^{+2} .

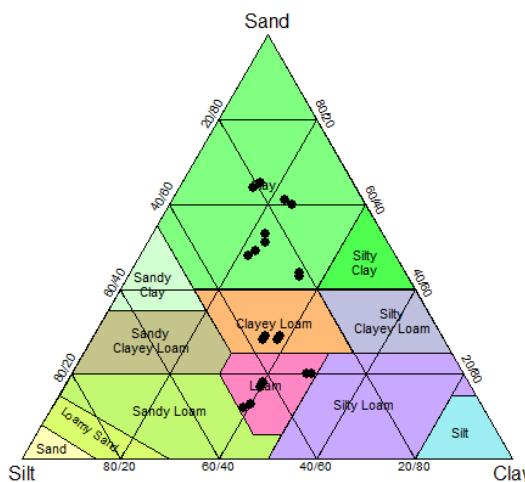


Figure 2: USDA Textural triangle showing soil textural class of the Fetzara basin

Table 1: Descriptive statistics of the measured soil physicochemical properties (Min: Minimum; Max: Maximum; SV: Standard deviation; CV: Coefficient of variation)

Parameter	Min.	Max.	Mean.	S. D.	CV%
EC ($\mu\text{S}/\text{cm}$)	700.000	3600.000	1280.000	595.686	46.537
pH	7.400	8.280	7.911	0.218	2.759
Clay (%)	15.000	47.200	31.800	10.268	32.289
Silt (%)	15.000	49.000	30.100	10.457	34.742
Sand (%)	12.000	65.000	37.500	18.389	49.037
OM (%)	8.260	30.790	15.431	5.764	37.355
C (%)	4.800	17.900	8.777	3.400	38.744
N (%)	0.450	1.350	0.876	0.291	33.183
CEC (meq/100 g)	7.500	31.800	17.990	7.580	42.133
Na^+ (meq/100 g)	0.460	1.890	0.918	0.393	42.870
Ca^{+2} (meq/100 g)	10.500	28.400	18.275	5.581	30.539
Mg^{+2} (meq/100 g)	0.850	4.600	2.504	1.278	51.056
K^+ (meq/100 g)	0.340	1.080	0.591	0.226	38.156

Table 2: Classification of soil quality based on Organic C, Organic Matter, Total Nitrogen and C/N Ratio

Parameter	Range	Classification	Range (no. of samples)
Organic C (%)	<2 2 – 4 4 – 10 10 – 20 >20	Very Low Low Medium High Very High	- - 6-8.4 (13) 10.2-17.9 (7) -
Organic Matter (%)	<3 3 – 7 7 – 17 17 – 35 >35	Very Low Low Medium High Very High.	- - 10.23-14.45 (13) 17.5-30.79 (7)
Total Nitrogen (%)	<0.1 - 0.2 - 0.5 0.5-1.0 >1.0	Very Low Low Medium High Very High	- - - 0.54-0.76 (13) 1.08-1.35 (7)
C/N Ratio	<8 8 – 10 10 – 15 15 – 25 >25	Very Low Low Medium High Very High	7.88-7.64 (2) 8.37-9.46 (8) 10.63-13.26 (9) - -

Table 3: Correlation coefficient (r) between soil properties

Parameter	EC	pH	Clay %	Silt%	Sand %	OM	C%	N%	CEC	Na ⁺	Ca ⁺²	Mg ⁺²	K ⁺
EC	1												
pH	0.44 8	1											
Clay%	0.22 6	0.101	1										
Silt%	- 0.05 5	-0.392	0.635	1									
Sand%	- 0.10 5	0.151	-0.907	- 0.901	1								
OM	- 0.11 5	0.397	-0.168	- 0.366	0.282	1							
C%	- 0.08 3	0.405	-0.095	- 0.306	0.209	0.973	1						
N%	0.09 7	0.527	0.329	- 0.060	-0.160	0.841	0.86 9	1					
CEC	0.00 3	-0.153	0.771	0.484	-0.698	- 0.314	- 0.25 9	0.053	1				
Na ⁺	0.67 1	0.115	0.420	0.245	-0.380	- 0.393	- 0.31 8	- 0.130	0.53 0	1			
Ca ⁺²	0.10 8	-0.037	0.786	0.509	-0.723	- 0.346	- 0.27 4	0.040	0.97 0	0.605	1		
Mg ⁺²	0.10 9	-0.084	0.508	- 0.765	-0.228	- 0.179	0.18 5	0.955	0.54 4	0.930	1	Mg ⁺²	
K ⁺	- 0.10 9	-0.144	0.518	0.272	-0.446	- 0.236	- 0.17 6	- 0.054	0.76 9	0.536	0.764	0.766	1

DISCUSSION

In north easting Algeria and specifically in the region of Fetzara Lake there is endorrheic area in the Mediterranean climate where shallow lagoons have salinity problems but related to seasonal changes. The values of soil EC indicate the saline nature of soils.

According to [28] the CV values indicated low (<10%) variability of soil pH and moderate (10 to 100%) variability of soil rest of the soil properties. Low CV values for soil pH was due to transformed measurement of hydrogen ion concentration. This variability is due to interaction of geological, pedological, microclimate and land use factors including soil management practices, fertilization and crop rotation on spatial scales.

The CEC is defined as the ability of a particle to change positive bases with the environment in which the particle interacts. Cations have the ability to be exchanged for another positively charged ion from the surfaces of clay minerals and organic matter. The most important exchangeable cations in the soil are calcium (Ca⁺²), magnesium (Mg⁺²), sodium (Na⁺), potassium (K⁺), hydrogen (H⁺), aluminum (Al⁺³) and ammonium (NH4⁺²). Knowledge of the CEC in the soil can be of great importance to characterize the soil on the content of ionic elements, concentration of clay and mud, texture, degree of compression levels of porosity and permeability, and supply information about the possible need for fertilizer. The CEC is an important soil property. High CEC may indicate high levels of clay, low permeability and internal drainage, due to high soil compaction. Already low levels of CEC may indicate a soil texture ranging from clay-sandy to sandy, with variable grain size and high permeability. Soils with low CEC, when they receive large volumes of rainwater to leech some of the ionic elements distributed in the A horizon by leaching,

leaving the soil depleted in nutrients. It is for this reason that sandy soils lose much more ionic elements (free form), which could be distributed to plant nutrition, than the clay soils and/or rich in organic compounds.

The CEC is mainly influenced by specific surface area of clay minerals. The soils had the highest values of CEC, and there may be a strong correlation of CEC with the high concentrations of clay present in these soils, since the clay on its surface has a strong negative charge, which attract positively charged cationic elements.

The main determinants of CEC are clay and cations exchangeable. This is because both have a negative electric charge strong enough to attract the positively charged cationic elements. Soils with different contents of clay minerals and cations exchangeable have different values of CEC. The Pearson's correlation analysis presented in Table 3 confirmed that there was significant correlation between CEC and clay ($r=0.771$), significant correlation between CEC and cations exchangeable (Ca^{+2} : $r=0.970$; Mg^{+2} : $r=0.955$; K^+ : $r=0.769$; Na^+ : $r=0.530$).

The total C and N in this study were determined about 8.7 and 0.87 g/kg respectively with C/N ratio about 10.52. The C/N ratio bellow 15 indicating that the soil on stress condition. The low of C/N ratio in this study is predicted as the impact of leaching on the top soil at the time of logging. In the other hand, that condition remind still not productive for all plant growth. Where, it has been reported that the ideal of C/N ratio for all plants are about 15.

In contrast, the concentration of cation in this study is higher. These results are supported by soil texture analysis which found contain higher percentage of clay. The increasing of sand in the soil is significantly reducing the capability of soil to hold cation; conversely, the increasing of silt and clay significantly increased the capability of soil to hold cation.

CONCLUSION

The aim of this study was to determine the chemical and physical properties and to describe the soil of Fetzara area. Surface soil samples (0-30 cm) showed the pH ranging from 7.4 to 8.28 showing characteristic of neutral to moderately alkaline soils. Contents of organic carbon and total nitrogen were the highest in the surface of examined soils. The C/N ratio reached usually relatively low and medium values in superficial layers of studied soils. Cation exchangeable capacity and sum of exchangeable base cations varied in samples of the soil profiles. The base cations can be lined up in the following sequence: $\text{Ca}^{+2}>\text{Mg}^{+2}>\text{Na}^+>\text{K}^+$.

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