ORIGINAL ARTICLE

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Estimating generalized of global impacts to water quality on soil characteristics in basin of the Great Sebkha of Oran

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Abstract

In basin of the Great Sebkha of Oran, water deficit linked to climate semi-aridity has forced farmers to resort to the use of underground water of poor quality, which considered as the major cause of soil degradation. The alluvial aquifer waters are particularly characterized by higher relatively concentration in dissolved salts when compared them with other aquifers of the same system. Generally, the salinity of the water increases from upstream to downstream in the direction of the Sebkha (Boualla et al. in Water Supply 17(6):1801–1812, 2017). Assessment of soil quality has become the basic work for agricultural sustainable development. The aim of this paper is to evaluate soil properties in great Sebkha of Oran basin. Geo-referred soil samples were collected from ten-component analysis, and different soils were analysed for different physical and chemical attributes. Our study focuses on mineralogical analysis and geochemical prospecting using soil chemical data. Eleven indicators were selected to constitute data to assess the soil quality: sieve analysis, classification, cation exchange capacity, pH, soil organic matter, conductivity, gypsum, nature of the oxide content, nutrients (NO_3-N, NH_4-N, PO_4-P), anions content (SO_4^{2-}, Cl^-) and mineralogical analysis. Conclusively, process and mechanism of soil quality need deep research.

Keywords Soil · Quality · Cation exchange capacity · Organic matter · Oxides · Leaching fraction

Introduction

The development of irrigation is accompanied, in the majority of the cases, by the appearance of process of salinization, alkalization of soils to varying degrees or sodization. It also allows the development of arable soil areas in arid and semi-arid. These situations are in close relationship with the natural features of the environment (soil and climate) and procedures for water management for irrigation whose quality is decisive.

Salinization of the basin of the great Sebkha of Oran, as with most of the soils in the Maghreb, is first of primary origin. Soils are actually made up of materials, alluvial, more or less dirty, from the erosion of the reliefs and alteration rocks. The material dissolved in water has a natural origin related mainly to atmospheric precipitation and lithology of crossed soil.

Secondary salinization is due to: (1) stagnation of water surface in the case of soils to bad sanitation and drainage; (2) recharge of the groundwater by sewage drainage; (3) rise of the water table salt and the strong evapotranspiration; (4) irrigation with waters at high risk of salinization and sodization; (5) lack of natural outlet for the evacuation of excess water drainage and sanitation; (6) compaction of soils; (7) chemical elements (chlorides, nitrates, etc.) are provided by the water in the ground at each irrigation and their concentration increases after each cultural cycle and after each year; (8) quantity of salt not used by plants and increasing each year; (9) concentration of the solutions of the area not saturated through evaporation during periods when the ground is bare; (10) re-infiltration of irrigation water is a potential source of degradation of the quality of groundwater, mainly in areas where the water flows at low depths from the surface

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of the ground (Antipolis, 2003; Aubert, 1976; Boualla, 2018; Lahlou et al., 2002; Maillard, 2001; Mimoune, 1995; Slama, 2004; Snoussi et Halitim, 1998).

In arid and semi-arid world areas, substantial hydraulic resources are available, but they are of poor quality (brackish). These zones cover a large part of the southern fringe of the Mediterranean countries. In these regions, the availability of water, their salinity and soil are among the main factors limiting productivity of the plants (Zid and Grignon, 1991).

Salinization of the soils in these regions is related not only to climatic conditions (strong sunlight and low rainfall) but also to the use of often poorly controlled irrigation, leading to a build-up of dissolved salts at the surface (Rahmoune et al. 2001).

Basin Sebkha of Oran is characterized by a semi-arid climate, when parent rock material is affected by the climate and vegetation, soil formation begins. Important aspects of the training of these soils are the following: daily changes in temperature, which causes the disintegration of rocks by physical processes; -the sand laden winds abraded the exposed surfaces of rocks (Boualla, 2018).

The physical disintegration of rocks gives relatively large fragments; only chemical erosion can break them down into smaller pieces. The process of chemical erosion is slow in arid due to water deficit characteristics. On the other hand, the extended periods of water shortage are important and, thus, do not result in the elimination or leaching of soluble salts which the accumulation is reinforced by the strong evaporation. The brief periods of water run-off do not allow deep penetration of salts (which are not transported distance), where are accumulated in closed depressions.

Geological and hydrogeological context

The basin of the great Sebkha of Oran is located in northwestern Algeria (Fig. 2). It extends over an area of 1890 km^2 of which 298 km^2 is occupied by the Sebkha. This Salt Lake extends over 40 km long with 6–13 km wide (Boualla et al. 2017).

Geological studies have highlighted a structure consisting of three estates: a native bedrock ante-nappe Mesozoic forming the backbone of the Massif to schistosity of Murdjadjo, to the north; a complex of allochthonous units put in place in the Miocene forming the Tessala Mountains to the south; and sedimentation post-nappe Neogene and Quaternary, subsiding in the central area. The formations thus defined generally have lateral variations in thickness and facies (Fig. 1).

The aquifer system is made by stacking, depending on the location, two to three layers of aquifers: the Miocene limestone, sandstone and sandy Pliocene and Quaternary alluvium (Boualla et al. 2017).

Materials and methods

For a best characterization of soils quality in times of low water, ten samples were collected (10 June 2013) (Table 1), from the bed of the main water courses, meant to eliminate the strong contributions during the rainy. The following laboratory tests are performed on these samples : the particle size, pH, electrical conductivity; the dosage of the limestones full and active, phosphates, sulfates, chlorides, nitric and ammoniacal azote, of carbonic gas, organic matter; the determination of the cationic exchange capacity. The diffractometrie x-ray was carried out to the MLC Materials Chemistry Laboratory (Univ-Oran 1 Ahmed BENBELLA) and further chemical analysis by methods Classics (in accordance with the standard NF EN 196-2) in the laboratory of the cement plant of ZAHANA (Fig. 1, Table 2).

Results and discussion

Sieve analysis

Sieve analysis particle distributions are grouped into several fractions (Fig. 2). The upper limit is 2.4 mm. Items greater than 2.4 mm appear not so in graphics. Analytical results are obtained in the form of decreasing cumulative particle curves and frequency histograms. We have adopted Folk and Ward (1957) equations for the calculation of indices of particle forms. These indices were used to establish dispersion diagrams (Maanan 2003).

Analysis of cumulative curves allows to distinguish three types of facies: logarithmic facies to sub-logarithmic, to clayey dominance, characterizing especially quiet environments; the sediments are deposited by excessive load at the decrease in the speed of transport (Fig. 2); hyperbolic facies, to silty–clayey dominance, characterizing especially quiet environments or areas; the sediments are deposited by decantation of uniform suspensions (Fig. 2); and parabolic facies, predominantly sandy, characterizing especially restless circles (Fig. 2).

The soil texture is essentially sandy. It would be related to the processes of aggradation. The weak structuring of soils and the climatic aggressiveness of the zone reinforce the sandy texture of the coarse material in place and lead to an enrichment in sand. The report coarse sand/sand, in terms of percentage of refusal, is in the order of: Dayet Bagrat 16.26; Besbes 3.7; Bredeah 6.9. El Hamoul 2.4; Haimer 91.1; Hamou Ali 2.83; Oued Tafaraoui 3.9; Rassoul 34.5; Sebkha 4.94; Oued Tamazourah 2.75. The granulometric study of the sandy fraction is used to
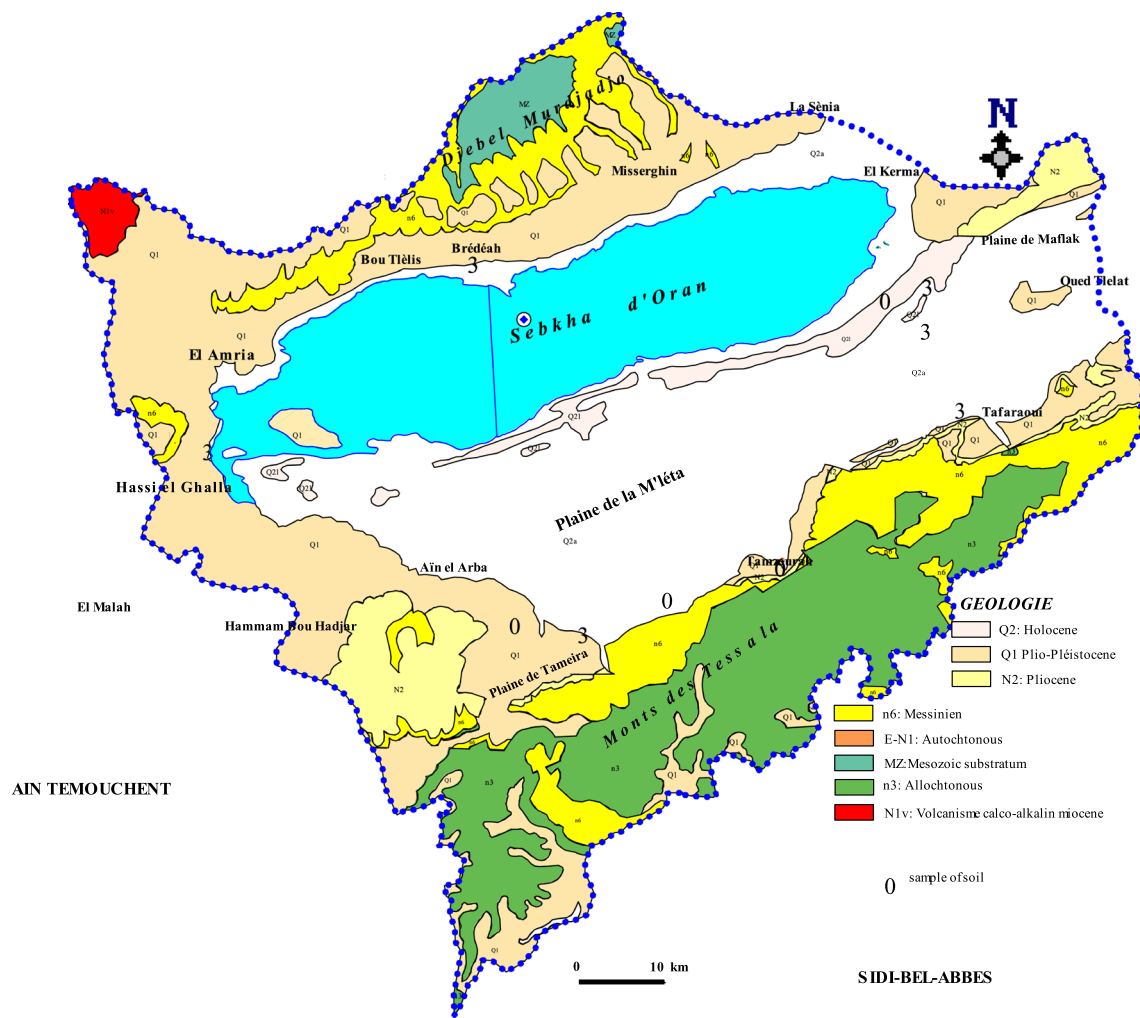
Fig. 1 Geological map (Benziane 2013) and location of sampling points of soils

Table 1 Network measurement and sampling of soils

No.	Name	UTM		
		X	Y	Z
1	Coteau El Hamoul	719.215	3935.993	130
2	Dayet El Bagrat	721.701	3936.899	104
3	Hamou Ali	721.619	3934.336	110
4	Oued Tafraoui	723.6	3929.71	156
5	Oued Tamazourah	713.1	3920.378	188
6	Oued Rassoul	706.5	3918.5	163
7	Oued Haimer	701.6	3916.599	165
8	Oued Besbas (Oued telata)	697.6	3917.024	153
9	Sebkha	679.687	3927.293	90
10	Station Brédéah	695.175	3938.228	93

characterize the deposits and to inform us, therefore, on the factors governing sediment transport and the conditions for their introduction (Maanan 2003).

Classifications of the studied soil are summarized in Table 3. The average grain size of soils is between 1.081 and 7.033 mm (Table 3). According to Folk and Ward (1957), the contents of the different grain size fractions show variations that distinguish two types of defined facies: a silt–clay facies characteristic of the sites of Dayet Bagrat, Bredeah, El Hamoul, Oued Haimer, Hamou Ali and Oued Tafaraoui, and a sandy facies, very fine for Oued Besbes, Oued Rassoul, Wadi Tamzourah and means for the case of the Great Sebkha.

The high content in silt and sand (less active) reduces the value of the specific surface area of soil assessed between 13.95 and 41.86 m^2/g, according to the method of methylene blue. It was shown, in the literature, that sandy soil (porous) promotes pollution of wells by nitrates (Table 4).

The granulometric mode (MO) (mm) corresponds to the maximum percentage of the histogram of the simple frequencies. This analysis shows a unimodal sand for each

Table 2 Method and apparatus

Parameter	Method and apparatus
Sieve analysis	Dry method
pH	pH—portable meter, HANNA instrument HI 9811
σ	Conductivimeter, Conductivity Meter MeterLab CDM 230
CO_2	The method Anne modified (spectrometry) at a wavelength of 585 nm
Organic matter	% Organic carbon $\times$ 1.724 = % MO
Total and active limestone	Calcimeter Bernard and Drouineau–Galet method
PO_4^{2-}	Spectrometry (dissolution of soils)
NO_3-N	
NH_4-N	
SO_4^{2-}	Gravimetric method with $BaCl_2$
Cl^-	Argentometric method
CEC	Method with $BaCl_2$

Fig. 2 Particle size distribution of soils
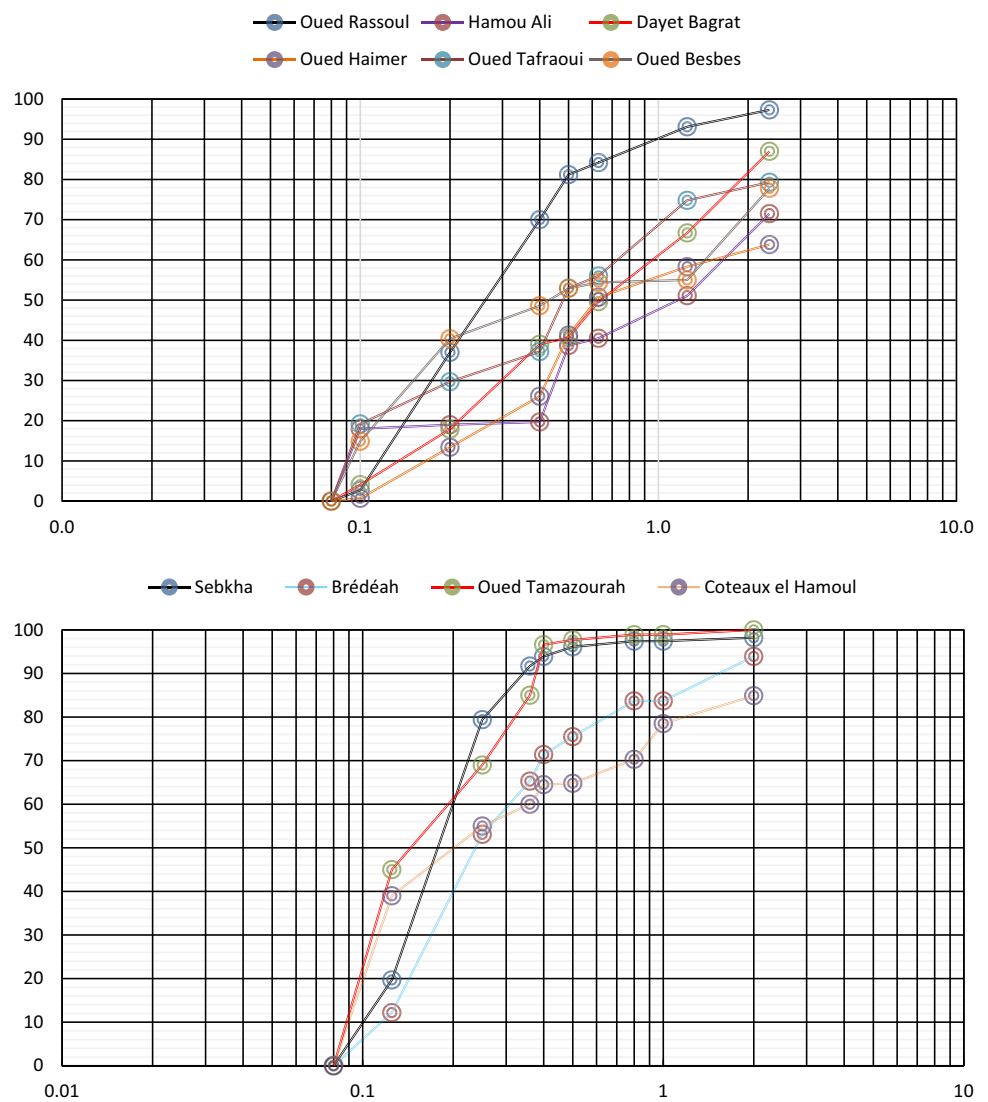
Table 3 Different size classes of soil particle indices

	Dayet El Bagrat	Oued Besbes	Brédéah	El Hamoul	Oued Haimer	Hamou Ali	Oued Tafraoui	Oued Rassoul	Sebkha	Oued Tamzourah
MO	0.600	0.600	0.800	0.600	0.600	0.500	1.300	1.300	0.400	0.400
Φ	6.015	3.622	4.164	5.534	4.624	7.033	6.906	2.751	2.057	1.081
σ_{Φ}	6.969	0.009	5.135	8.432	6.182	8.140	6.844	7.316	5.088	7.152
SkI	0.860	0.681	0.885	0.925	0.925	0.880	0.689	0.696	0.874	0.631

type of soil with values ranging between 0.08 and 0.250 mm (Table 3).

Overall, the soils are extremely misclassified ($\sigma_{\Phi} > 4$), except for the case of Oued Besbes which, instead, presents a very well-ranked ground. Their indexes of the skewness show asymmetrical positive cumulative curves to fine sediments, which marks their significant heterogeneity (Table 3).

Chemical characterization

In the surface horizons, soil pH is between 7.2 and 7.9. The soils are slightly alkaline. Their electrical conductivity varies between 0.63 and 24.41 mS/cm (Table 4). The values for this setting are increasing in the direction of the Sebkha, where they reach the maximum of 24.41 mS/cm. They indicate significant horizontal and vertical variations in the soils due to the lithological heterogeneity and the presence of water table.

Electrical conductivity reflects the salinity or non-salinity of soils. It is in our case influenced as well by the evaporates and carbonates. Except the Sebkha that has a high salinity, the other sites sampled are moderately to weakly saline.

The concentration of dissolved salts varies widely under the combined influence or not of various factors such as the physical characteristics of the soil, the capillary basement water upwellings and climate. In the summer, it is accelerated by evaporation.

Chemical analysis performed on rainwater revealed relatively significant rates of sodium chloride. These contents are reduced on the side towards the interior of the country. Above the salt lakes, aerosols consist essentially of sodium chloride crystals which can play, in the atmosphere, the role of nuclei of condensation of water vapour (Benziane 1983).

Also, the binding effects of demineralization of the waters of Bredeah station will be taken into account. Indeed, since its commissioning in 2004, the plant of wastewater treatment, designed to supply drinking water to the urban group of Oran, rejected its brines in the nearest outlet. These natural salts as sodium chloride, would in view of their high solubility, spread on soils and dissolved in plain water. This catastrophic situation, which have lasted for a few years, gave a serious blow to the environment, particularly to farms.

Sulphate concentrations are greater than those of chlorides. They are, roughly, the same for all samples. However, the soils south of the Sebkha contain significantly more. These relatively high rates are related to the Triassic gypsum contributions of the Tessala. Chlorides appear relatively homogeneous but in small quantities. Throughout the chemical analyses, only the sample in the Sebkha showed a significant rate. The analyses show that soil levels have zero active limestone. The latter would be represented by the percentage of the clayey fraction below

Table 4 Physico-chemical parameters of the studied soils

No.	pH	σ (mS/cm)	SS (m²/g)	MO (%)	Gypsum (g/100 g de sol s)	SO_4^{-2}	Cl^-	CO_2	CEC (méq/100 g)	NO_3-N (mg/l)	NH_4-N	PO_4^{3-}
1	7.2	2.95	41.86	88.06	9.68	11.55	1.42	50.9	29.64	3.48	48.51	Absent
2	7.9	8.37	41.86	80.15	16.46	10.85	2.84	46.33	29.95	Absent	14.13	Absent
3	7.6	1.17	13.95	93.02	19.36	10.07	1.78	53.77	32.84	8.55	43.45	Absent
4	7.5	0.78	27.91	99.6	19.36	11.18	0.35	65.63	38.74	4.3	45.05	Absent
5	7.6	1.14	27.91	92.84	19.36	12.4	1.06	53.66	32.78	17.18	63.16	Absent
6	7.7	0.63	13.95	97.25	6.78	10.16	0.71	56.21	34.61	17.31	59.79	Absent
7	7.7	0.9	13.95	98.9	26.33	13.74	1.78	69.94	42.14	3.34	43.71	Absent
8	7.9	1.32	13.95	97	16.46	13.55	1.136	59.48	37.35	160.33	48.39	Absent
9	7.3	24.41	13.95	90.52	19.36	10.61	31.24	52.32	30.79	100.46	42.05	Absent
10	7.7	2.18	27.91	91.99	19.36	10.17	0.85	53.17	32.94	3.48	41.63	Absent

2 μm (absent on the particle curves), which allows to avoid the appearance of the phenomenon of chlorosis.

The absence of active limestone is probably related to its positive relationship with organic matter. This relationship suggests a role of this limestone in the protection and conservation of organic matter (Callot and Dupuis, 1980). Active limestone plays an inhibitory role for the protection of the organic matter against the rapid mineralization, forming a film surrounding the particle organic and preventing micro-organisms to reach it (Duchaufour 1977). In fact, the estimation of organic matter level is based on the content of soil clays and that of limestone (Soltner 2000).

The levels of organic matter (MO) of the studied profiles surface horizons vary between 80.15% and 96.60% (Table 4), with an increase in carbon dioxide. The relatively high latter levels are due to probably fertilizer soil amendments, the presence of organic waste and an accumulation of organics from agricultural areas. There are two phenomena of degradation of the organic raw: the fastest is the mineralization of the labile fraction by releasing soluble mineral compounds (ammonia, nitrates, phosphates, sulphates) or gaseous (dioxide of carbon or CO_2) and the slower is the humification, transforming the raw organic material into humus.

Through this double process of mineralization, the organic matter does not accumulate in the soil: its content increases in a virgin soil. According to Sparks (1996), 25–95% of the cationic exchange capacity is given by the organic matter in the soil, which explains the high levels of very high CEC. The CEC decreases as the organic matter is mineralized and when the soil becomes more acidic or more oxidant. Organic matter is also allocated based on soil despite management types which are bit different by intensity of mineral fertilization and production (Hassine et al. 2008). Terrigenous contributions are also an additional source of organic matter (Maanan 2003).

There is a slight enrichment in total limestone throughout the soil. A maximum value in gypsum was recorded in Oued Haimer. Hassani (1987) has demonstrated that no principal river flows from the Tessla mountains. Those who manage to drain in the Plaine of the Mléta are secondary and less important, because of their young age, and for some of them, the storm water drainage basins consist of salt outcrops and gypsums. During a flood, these basins will widely contribute to the transfer of salinity from upstream to downstream.

There is no relationship between the total limestone and organic matter. Total limestone consists of debris in the size of grains of sand with no direct link to organic matter (Hassine et al. 2008). It confirms by the values obtained, between 6.78 and 26.33% (Table 4), classifying the soils of the basin as it is slightly to moderately calcareous (standard norms of interpretation of soil limestone level (proposed by GEPPA (Baize, 1988)). Beyond 5%, natural calcium reserves and their gradual release by dissolution under the effect of rainfall and chemical and biological soil activity, makes it prevents any liming process in soil for long-term. The soils are systematically basic.

The absence of phosphates is due to the phosphorus fixation on the organic matter, which prevents it from behaving like an anion and associating with oxygen to PO_4^{3-} ion form. This observation allows us to conclude that organic phosphorus is not very important in these soils; intensive crops prefer the storage of phosphorus in mineral form (Brossard and Laurent 1988). Nitric and ammoniacal nitrogen is unstable. For Oued Besbes and Sebkha, the NO_3^- values are largely superior to those of NH_4^+. This is the phenomenon of the nitrification process which is the consumption of ammonium by microbial activity in soil and its transformation into nitric nitrogen. For the other points, there is a phenomenon of denitrification where nitric nitrogen is transformed into nitric gas N_2.

Composition chemical of the major elements of the soil, presented in oxidized form, is expressed as a percentage by

Table 5 Chemical composition of soil (%)

Code	SiO$_2$	Al$_2$O$_3$	Fe$_2$O$_3$	CaO	MgO	SO$_3$	K$_2$O	Na$_2$O	P$_2$O$_5$	TiO$_2$	LOI
1	27.81	8.68	3.06	21.49	1.2	14.71	1.2	0.04	0.1	0.36	20.69
2	34.52	10.37	4.08	18.3	1.92	0.34	1.88	0.26	1.79	0.46	25.69
3	44.59	14.46	5.9	12.37	1.84	0.12	1.75	0.3	0.19	0.71	17.28
4	33.03	9.41	4.83	24.53	1.46	0.19	0.88	0.32	0.14	0.38	24.2
5	38.99	7.58	3.1	21.83	1.42	0.84	0.81	0.22	0.14	0.32	21.99
6	24.24	4.51	4.08	34.25	1.27	0.68	0.37	0.3	0.11	0.16	29.46
7	48.08	6.16	4.01	20.09	0.98	0.26	0.74	0.12	0.07	0.25	18.69
8	56.52	10.16	4.46	6.05	1.8	0.72	0.91	1.86	0.08	0.59	16.38
9	33.71	10.24	3.79	18.98	2.42	1.22	1.36	0.59	0.76	0.44	26.26
10	40.56	8.03	4.77	21.17	1.57	0.32	0.92	0.2	0.1	0.35	21.23

LOI loss on ignition

mass for the different samples (Table 5). Test results show very different values.

Studied soils consist mainly of SiO$_2$, CaO and Al$_2$O$_3$. These three oxides alone account for more than 50% by weight of the total fraction of samples.

The analysis of samples (Table 4) shows: -a very high content of SiO$_2$ in Sebkha and Oued Besbes, indicating an enrichment in silicate minerals; (2) Al$_2$O$_3$ concentrations indicate, in general, the abundance of the clayey fraction in all samples; (3) the SiO$_2$/Al$_2$O$_3$ report reflects the excess of silica, illustrating the effect of dilution of the clayey fraction in silica; (4) Fe$_2$O$_3$ content varies between 3.06 and 5.9%. The highest rate is recorded at Hamou Ali; (5) MgO concentrations are relatively high in Dayet El Bagrat and Bredeah station; (6) CaO levels are overall high, notably in the Oued Haimer and Tafaraoui, reflecting a significant proportion of calcium carbonate. These two sites are made up mainly of carbonate deposits rich in organic matter; for the Haimer Oued, which has the highest concentration in CaO (34.25%), coupled with high MgO content and a low Al$_2$O$_3$ content, this indicates that the ground would come from pedogenetic evolution of dolomitic training. (1) MgO levels range from 0.98 to 2.42% across samples. (2) Low K$_2$O levels can be attributed to intense leaching, leading to the formation of lateritic soils impoverished mobile cation (mostly K$^+$ and Na$^+$) (Chamley 1989); (3) the presence of phosphate nodules fully explains the high levels of P$_2$O$_5$, between 0.1 and 1.79%; these levels are of course connected with anoxic events which have resulted in massive soil fills of organic matter and associated phosphates (skeleton of body); (4) the presence of TiO$_2$ contents is probably related to minerals containing Ti (rutile, ilmenite and sphene for example); (5) loss on ignition is mainly due to the abundance of H$_2$O and CO$_2$ in relation to carbonates; this loss is high in samples of Dayet El Bagrat, the Station of Bredeah and Oued Haimer (Carpentier 2007).

The analyses carried out on samples of Oued Tamzourah and Oued Rassoul usually has low concentrations for the majority of the elements. For all samples, the highest levels relate for (SiO$_2$) and CaO oxides, and a smaller proportion for (Al$_2$O$_3$); where would correspond to silicates and carbonate minerals. The oxides of Al, Fe, K, Mg and Ti, and part of the silica, are mainly of detrital origin. We hold that the factor of first order controlling the variability in most of the elements analyzed is the dilution of the detrital phase by calcium carbonate (Carpentier, 2007).

Mineralogical analysis by DRX

Samples show a probability of the presence of crystalline phases mainly in the form of: quartz (SiO$_2$), dolomite (CaMg(CO$_3$)$_2$), calcite (CaCO$_3$) and illite ((K,H$_3$O)(Al,Mg,Fe)$_2$(Si,Al)$_4$O$_{10}$[(OH)$_2$,(H$_2$O) (Hirmas et al. 2012; Ali-Dahmane et al. 2014) (Fig. 3).

Calculation of the fraction of leaching of soil salt

In arid and semi-arid regions, Irrigation of saline soil requires a large quantities of water that exceed the amounts of regular irrigation for agriculture this large amount of water helps to wash the soil from salts and push them to the depths. There is a method of prediction of leaching volume: usually used (conventional method, recommended by FAO), which neglects the precipitation of minerals from soil solution.

Initially, the leaching fraction (LF) has been set for a long-term calculation. However, more recent works uses it for the duration of a single campaign (Bresler and Hoffman 1986). Similarly, the spatial variations in salinity, related to the heterogeneity of water inputs on the plot (Miyamoto and Cruz 1986), cannot be taken into account by the notion of leaching fraction (LF). The concept of leaching fraction thus defined in this way poses as a condition that the water drained out of the profile is in balance with the ground: it is only once this condition has been realized that the formulas which involve electrical conductivities can be developed.
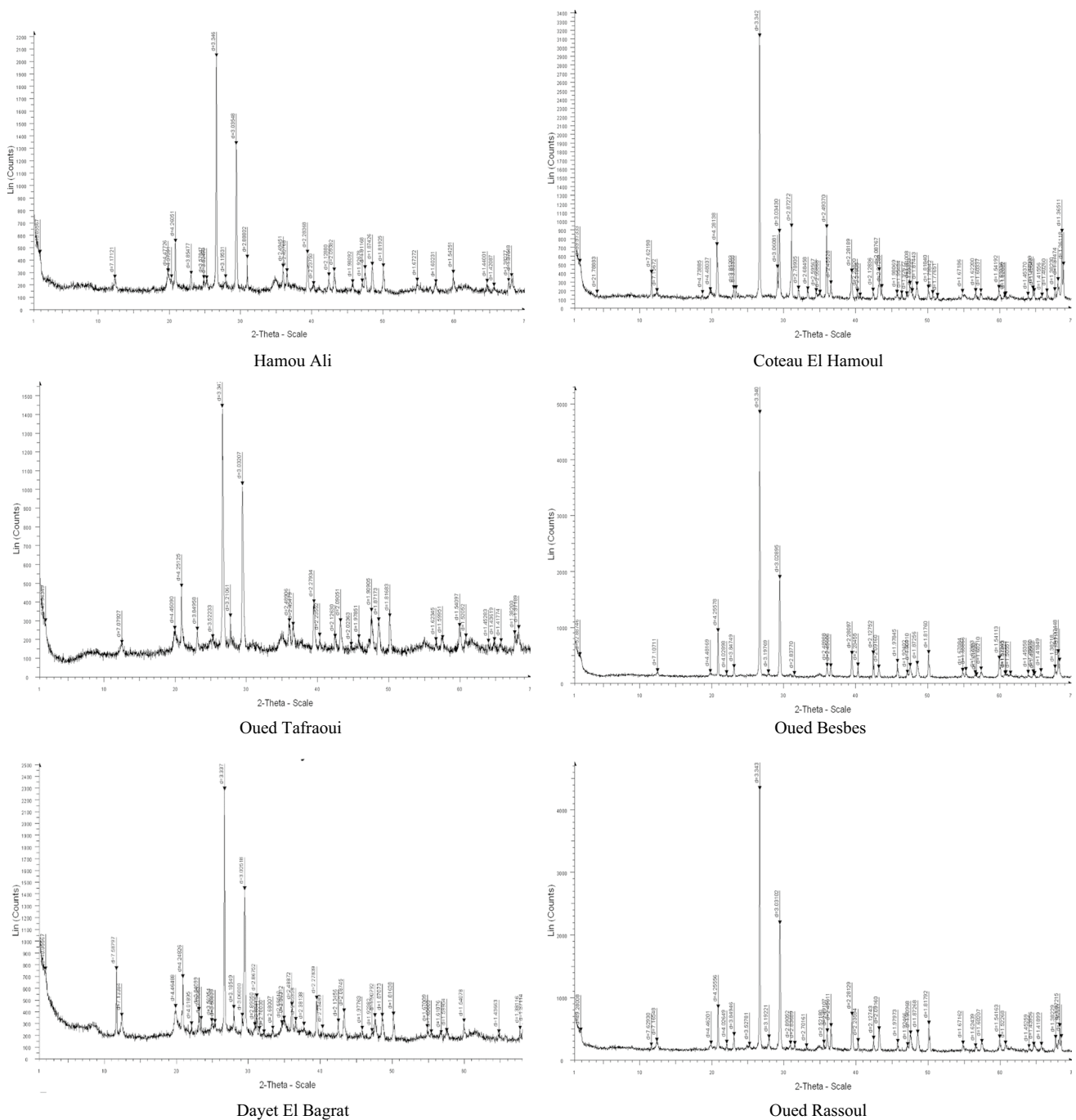
Hamou Ali

Coteau El Hamoul

Oued Tafraoui

Oued Besbes

Dayet El Bagrat

Oued Rassoul

Fig. 3 Mineralogical analysis

So, knowing the electrical conductivity of irrigation water ECi, and the average electrical conductivity of the extract from dough saturated that it does not exceed the root profile ECesm, it is possible to establish a relationship linking ECesm and ECi to the fraction of leaching (Rhoades 1974). This requires a number of assumptions: (1) the saturation extract and irrigation water have the same composition on the surface; (2) the steady state is reached and the salinity varies more than 1 year on the other; (3) the conductivity is proportional to the concentrations; (4) the conductivity of the saturated paste extract is supposed to be equal to half of that of the solution from the ground to the field capacity; (5) the useful depth of the soil is divided into four quarters and we assume that 40% of evapotranspired water comes from the first quarter, 30% of the second, 20% of the third and 10% of the last; (6)
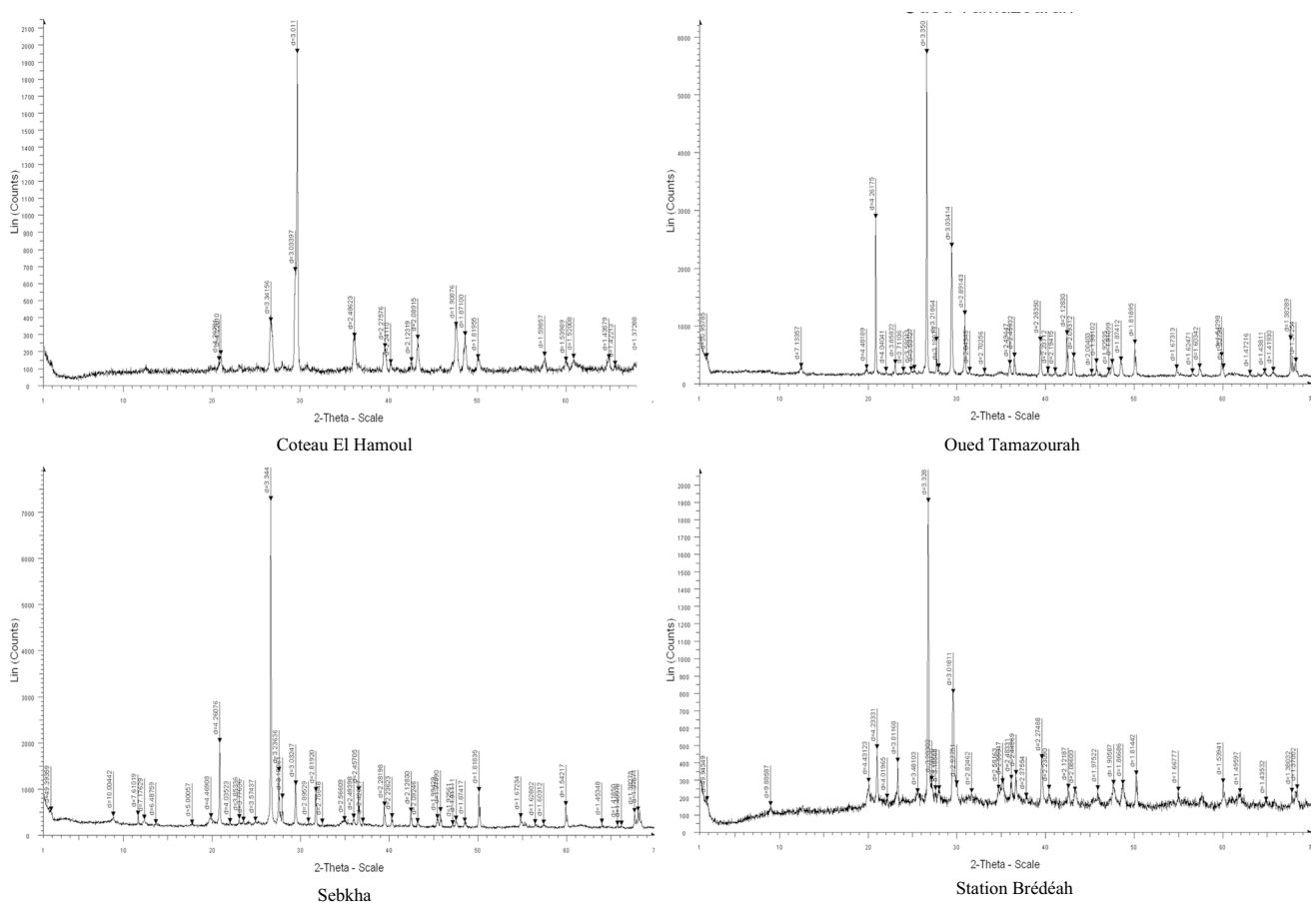
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Coteau El Hamoul

Oued Tamazourah

Sebkha

Station Brédéah

Fig. 3 (continued)

Water irrigation does not dissolve any mineral and does not participate in any precipitation (Boualla, 2018). In our case, from the data that could be collected, the second and fourth conditions are not satisfactory.

Conclusion

Agricultural intensification is accompanied by, no doubt, an abuse of agrochemical inputs and a reckless pumping of groundwater, which are becoming less and less abundant and of poor quality. This leads to a problem of overfertilizing. A number of field observations clearly show an excessive enrichment. Overexploitation of these resources, coupled with the phenomenon of drought, inevitably leads to degradation of soils and waters, which result in problems of salinization, sodization and deterioration of soil structure. The salinization of Sebkha Oran basin, as for most soils of the Maghreb, is initially of primary origin. The soils are in fact made of alluvial materials, more or less salty, resulting from the erosion of the reliefs and the alteration of the rocks.

Soil salinization in these regions is related not only to climatic conditions but also to the often poorly controlled use of irrigation, which results in an accumulation of dissolved salts on the surface (Rahmoune et al. 2001).

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