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Physico-Chemical Characterization of Water and Soil of the M'nasra region in the Gharb plain (Northwest Morocco)

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Abstract

This work is to carry out an evaluation of the quality of agricultural soils and water in the irrigated area of the M'nsara region in the Gharb plain with the goal of describing the degree of degradation of natural resources and improve the sustainability of the environment and irrigated farming systems of the region through optimal management of these resources. Eighteen water and nineteen soil samples were collected based on existing soil and piezometric maps of the irrigated areas, distributed into 3 different zones: A, B, and C. Characterizations of the main parameters of soil and irrigation water quality were made. Irrigation water salinity varies between 0.5 and 1.3 dS/m. The irrigated soils from the groundwater have shown a secondary salinization superior to that of irrigated soils by the waters of the dam. Cultivated soils present a salinity that reaches 1.90 dS/m in some areas. The results show that 68.4% of the soil samples are poor to moderately poor in organic matter. The sodium adsorption ratio (SAR) shows a minimal risk to accumulate sodium in the soil with 16.7% is slightly alkaline. The soils are weakly to moderately basic and represent respectively 73.7 and 10.5 % of the study area. Potassium and available phosphorus have very low values in the majority of soils which will have a negative impact on the environment. The parameters was performed by the determinsitc method of inverse distance weighted (IDW). In order to delineate areas that are a priori subject to environmental degradation in order to understand the effect of agricultural intensification on the sustainability of natural resources, taking into account the type of management water irrigation in the arid region.

Keywords: Gharb plain, M'nasra , Morocco, Physico-Chemical, Soil .

1.Introduction

In Morocco, the degradation of soils and waters is a problem that accumulates and amplifies [1]. This pollution decreases the potential of the water resources of good quality and generates health risk for rural population [2,3]. Previous studies have targeted the quality of waters and soils in the irrigated perimeters in Morocco [2,4-6]. All over the world, studies have stressed the problem of degradation of soil and groundwater quality [7], which can limit the long-term agricultural production and cause irreversible deteriorations. Morocco is characterized by an arid and semi-arid climate with a rainfall regime dominated by a strong irregularity in space and time. Natural water resources in Morocco are among the lowest in the world. Agriculture represents 15% of the gross domestic product of Morocco. It is responsible for 88% of the total water demand in Morocco [8]. Irrigated agriculture is also the principal driver for ensuring food security and economic development. The agricultural activities in the Gharb (Morocco) are considered to be among the potential factors that may contribute to the degradation of the quality of water and soil. The objectives of this work are to describe the degree of degradation of natural resources and improve the sustainability of the environment and irrigated farming systems of the plain through optimal management of these resources.

2. Materials and Methods

2.1. Study Area

The surface area of the Gharb region is 600 Km2. The region is dominated by sandy and clayey soils. The climate is Mediterranean with annual precipitations ranging between 480 and 600 mm, and the average temperature is 27°C in summer and 13°C in winter (Office Régional de Mise en Valeur Agricole du Gharb). The water samples were collected from 18 wells (less than 50 m depth) installed in 19 sites located on the coastal zone of M'nasra in Gharb region, Northwest of Morocco (Figure 1). The levy has been carried during the year of 2017. Water samples were collected in 1l clean plastic bottles and stored in the freezer (-10°C) until their analysis. Soil samples were collected from the 0-20cm depth using an auger. They were dried in the open air and then crushed and sieved.

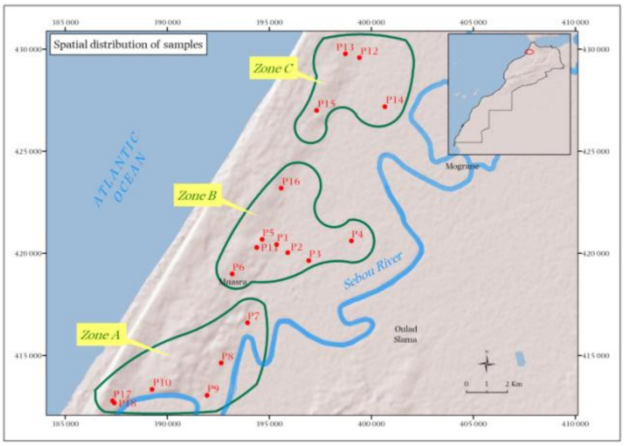

Figure 1.Map of the M'nasra zone with the sampling points.

2.2. Sampling and Laboratory Analysis

The measurement of electrical conductivity (EC) and hydrogen ion concentration (pH) were performed in situ using the Jenway 3510 pH-meter. Calcium (Ca^{2+}), magnesium (Mg^{2+}), and chloride (Cl^{-}) were measured by the titrimetric method. Carbonates (HCO_3^{-}), and sulfates (SO_4^{2-}) were determined using Jasco V-530 UV/VIS spectrophotometer. Sodium (Na^{+}) was determined using the Jenway Clinical PFP 7 flame photometer. Those measurements were performed according to the AFNOR standards [9]. These samples were analyzed for the following physic-chemical

parameters: pH (water), electrical conductivity (EC), organic matter (OM), available phosphorus (P_2O_5), and exchangeable potassium (K_2O). Soil texture component (clay, sand, and silt) percentages were calculated using the Robinson pipette method [10] at the laboratories of the National Institute of Agricultural Research (INRA), Rabat.

2.2.1. Geology

The area corresponds to the Western edge of the subsident basin of the Gharb. It is located in the area of contact between the two major structural assemblies of Morocco: the Western primary meseta which plunges gradually from the South to the North, and the Rifain field which belongs to the Alpine circummediterranean domain [11]. Since the beginning of its training at the Neogene, the basin has been the seat of a thick sedimentation detrital character [12].

2.3. Mapping and Chemical Analysis

The mapping of the physico-chemical parameters was performed using the ArcGIS software (ESRI), version 9.3 .The distribution maps were generated using the Inverse Distance Weighting (IDW) interpolation method [13, 14].The statistical parameters (minimum, maximum, average ,and coefficient of variation) were determined for the 11 observed and calculated water (EC, Ca^{2+}, pH, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, HCO_3^{-}, CO_3^{2-} and SAR) and soil (pH-H_2O,OM, P_2O_5, K_2O, Na^{+}, ECs and ESP) quality parameters . These statistical computations were performed using the SAS software [15].

3. Results and discussion

3.1. Characterization of the Irrigation Water Quality

Descriptive Statistical Parameters of Water

The main descriptive statistics of the quality parameters of the analysed water (EC, pH, cations and anions and SAR) are reported in Table1.

3.1.1.Cationic and Anionic Composition

The most variable element is K with a coefficient of variation (CV) of 201.9 %, although it is among the major constituents with a mean value of 3.8 ppm and values ranging between 0.3 and 31.3 ppm. The second most variable constituent is Mg with a CV of 87 %; it is still a major element with a mean value of 30 ppm and values ranging between 2.6 and 102 ppm. Many other constituents are major elements like Na (mean of 47.6 ppm) and CO_3 (mean of 29.2 ppm) which are the predominant cations. SO_4 (mean of 153.5 ppm), and Cl (mean of 138.5ppm) are predominant anions, whereas others are minor elements like HCO_3 (mean of 267.7ppm) and Ca (mean of 54 ppm). To summarize, the importance in average of cations is Ca >Na > Mg > K, while for anions it is HCO_3>SO_4 > Cl > CO_3. However, this importance may vary from one observation to another; depending on the spatial location where the sample was taken which in turn is a function of climate, parent material, anthropogenic activities, etc. In comparing our results to some recently published research works, there is a difference in the order of the major cations and anions. For example, from a study based on 36 groundwater samples from the Souss-Massa(Morocco), El Oumlouki et al. (2018)[16] found that the most abundant cation was Mg followed by Na whereas in our case, it was the inverse. In contrast, Srinivasamoorthy et al. (2014)[17] found that, in a study of 87 groundwater samples in India, the most abundant anion was HCO_3 followed by Cl compared to our study where HCO_3 was abundant followed by SO_4 .

Table 1. Descriptive statistic of water quality parameters in the M'nasra zone.

Parameter	Min	Max	Mean	CV (%)
EC (dS/m)	0.5	1.3	0.8	34.2
pH	7.3	8.1	7.7	3.6
Ca^{2+}(ppm)	32.0	76.0	54.0	25.3
Mg^{2+} (ppm)	2.6	102.0	30.0	87.0
Na^{+}(ppm)	10.7	130.6	47.6	72.9
K^{+} (ppm)	0.3	31.3	3.8	201.9
CO_3^{2-} (ppm)	0.0	90.0	29.2	67.1
HCO_3^{-} (ppm)	122.0	427.0	267.7	33.1
Cl^{-} (ppm)	63.9	262.7	138.5	46.6
SO_4^{2-} (ppm)	37.2	292.7	153.5	58.1
SAR ($mol^{½}\ l^{-1/2}$)	0.3	3.4	1.4	73.8

Min: minimum, Max: maximum, CV: coefficient of variation, EC: electrical conductivity, SAR: sodium adsorption ratio.

3.1.2.Salinity of Water

The maximum value of water EC is 1.3dS/m. If EC of water is less than 2dS/m, it is considered excellent for irrigation and crop production [18]. Based on the results presented in Table 2, we found that 61.1% of the analysed wells have slight to moderate salinity with 0.7 <EC< 3.

Table 2. Salinity classes of irrigation water of the M'nasra region following the FAO norms [19].

Restriction on use	EC(dS/m)	Number of wells	% of wells
No problem	EC<0.7	7	38.9
Slight to moderate	0.7<EC<3	11	61.1
Serious problem	EC>3	0	0.0

The map shown on Figure 2 illustrates the spatial distribution of the water salinity of the analysed wells.

This map shows that the majority of these wells have slight to moderate salinity, especially in the C (P12 and P14), A (P9, P10,and P18) and B (P11) zones. The maximum value of the salinity is located in the C zone, which is near the downstream of the Sebou River (Figure 2).

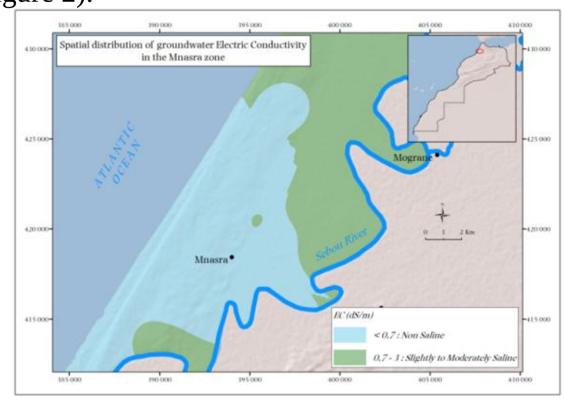

Figure 2. Spatial map of salinity of irrigation water of the Mnasra zone.

3.1.3. Sodium Adsorption Ratio (Alkalinity)

The alkalinity of irrigation water is evaluated using the SAR (mole$^{1/2}$ l$^{-1/2}$):

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

The higher the SAR, the more the water presents a risk of soil sodicity due to the exchange that will operate in the balance between Na^{+} in soil solution and Ca^{2+}/Mg^{2+} of the absorbent complex. Sodium acts on the deflocculation of the clay soil, resulting in decrease in the macroporosity (air) and the infiltration rate of water[20].

Table 3 and Figure 3 show that 16.7 % of the analysed wells are slightly alkaline. They are located on the upstream and downstream of the Sebou River (A and C zones, respectively).

Table 3. Alkalinity classes (SAR) of irrigation water of the M'nasra region according to the FAO norms [19].

Water quality	Alkalinity	SAR	Number of wells	% of wells
Non-alkaline	S1	0-3	15	83.3
Slightly alkaline	S2	3-6	3	16.7
Alkaline	S3	6-12	0	0.0
Highly alkaline	S4	12-20	0	0.0
Very highly alkaline	S5	20-40	0	0.0

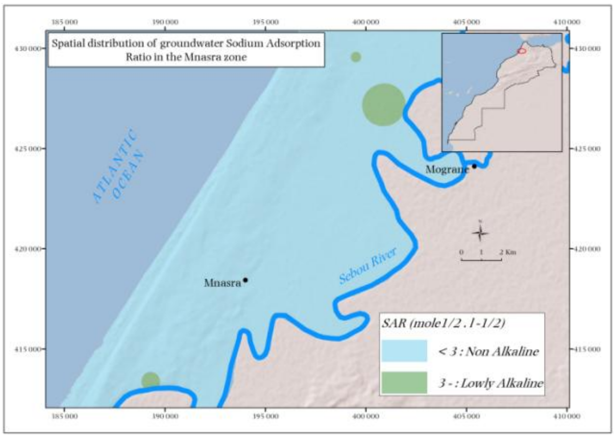

Figure 3. Spatial distribution of alkalinity (SAR) of irrigation water of the Mnasra zone.

3.2. Characterization of Soil Quality

3.2.1.Descriptive Statistical Parameters of Soil

The results of measurement of various physic-chemical parameters of the soils are presented in Table 4. If the coefficient of variation is large, the variability is very important .For the parameters K_2O, ESP,ECs and P_2O_5, the variability is quite important whereas for the other parameters, it is much less important. The interpretation of the variation of physical and chemical parameters such as pH, OM, K_2O, Na and ECs did not indicate any the effect of irrigation water on this parameters.

Table 4. Characterization of soil quality parameters within the M'nasra zone.

Cultivated soil characteristics				
Parameter	Min	Max	Mean	CV(%)
pH-H_2O	6.7	8.1	7.5	0.32
OM (%)	0.3	5.0	2.3	1.37

P_2O_5 (ppm)	42.4	282.7	140.0	66.3
K_2O (ppm)	0.1	129.6	28.0	40.44
Na^+ (meq/100g)	0.1	4.7	1.6	1.28
ESP (%)	8.7	715.0	130.4	149.6
ECs (dS/m)	0.2	1.9	0.6	58.5
Clay (%)	2.6	9.2	5.0	2.03
Silt (%)	2.1	7.5	4.0	43.2
Sand (%)	85.9	94.9	91.0	2.7

Min: minimum, Max: maximum, CV: coefficient of variation, ECs: electrical conductivity of soil, ESP: exchangeable sodium percentage.

3.2.2. Characterization of Soil Quality Parameters in the Study Zone

3.2.2.1.Soil pH

The pH is an important parameter of the dynamics of the soil. It is a key in agronomy because the levels of acidity or basicity of the soil plays a very important role in the assimilation, of nutrients by the plant, and it has an influence on three major components of the fertility of a soil: the bioavailability of nutrients, the biological activity and the structural stability, pH variation depends on the seasonal variations and the buffering capacity of soil (the number of ions in the reserve on the clayey-humic complex) ,the water status of the soil, its temperature and the presence or not of a crop in period of active growth phase [21,22]. The study distribution of the pH showed that 73.3% of the soil samples are weakly basic while 10.5% of them are moderately basic (Figure 4).

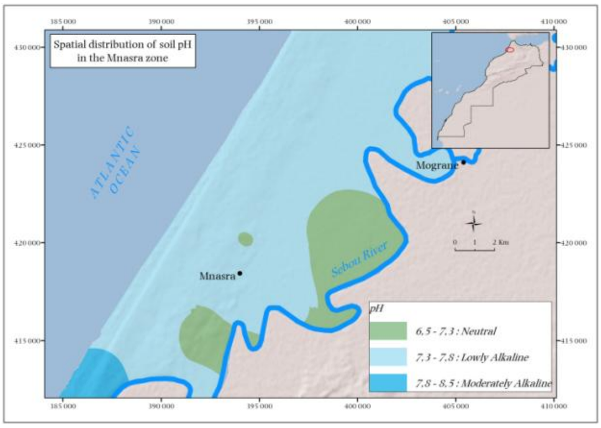

Figure 4. Spatial distribution of soil pH in the Mnasra zone.

3.2.2.2. Organic Matter

The organic matter of the soil is an important indicator of the quality of the soil [23-26] through its contribution in the stability of the soil, the increase in water-holding capacity of the soil, the fixing of mineral elements, and the substrate for microorganisms in the soil. The organic matter content of the soil is influenced globally by climatic factors, vegetation, the texture of the soil, the topographical conditions, influencing the microclimate and drainage and cropping practices [16]. The results show that the studied soils are poor to moderately poor in terms of organic matter, content 52.6% being moderately poor. This could be explained by the influence of climate and farming practices. In

fact, the farmers of the region do not leave much crop residues on the soil as well as they do not bring frequently organic amendments such as manure and compost which negatively impacts the quality of soils.

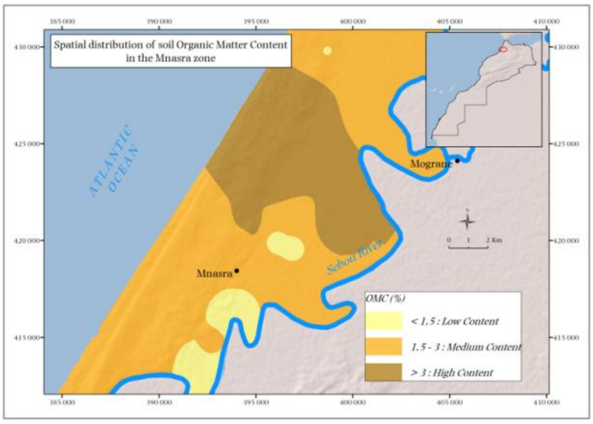

Figure 5. Spatial distribution of soil organic matter in the Mnasra zone.

The maximum value of the organic matter is 5% located in the C (P15) zone, which is near the downstream of the Sebou River (Figure 5).

3.2.2.3. Soil Salinity

The salinity of the studied soils was measured by the electrical conductivity of the saturated soil extract (ECs).The results are presented in Table 5 and on Figure 6. We note that 100% of the soil samples are non-saline.

Table 5. Distribution of soil salinity classes of the Mnasra zone according the FAO norms [27].

Class of soil salinity (C)	ECsp(dS/m)	Number of sites	% of sites	Effects on crop plants
Non-saline	0-2	19	100.0	Negligible effects
Slightly saline	2-4	0	0.0	Yields of sensitive crops may be restricted
Moderately saline	4-8	0	0.0	Yields of many crops are restricted
Strongly saline	8-16	0	0.0	Only tolerant crops yield satisfactorily
Very strongly saline	>16	0	0.0	Only a few very tolerant crops yield satisfactorily

The maximal value of the salinity is located in the A zone (P9), this is caused by the proximity to the Ouled Berjal waste discharge (Figure 6).Other factors that may explain salinity include soil texture and structure, drainage system efficiency and cultural practices. As a result, the soils of the studied sites do not show severe salinity problems. Nevertheless, a rational use of saline irrigation water is necessary for sustainable use of these agricultural lands.

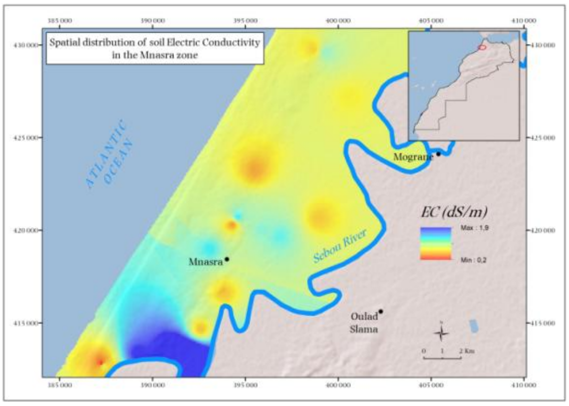

Figure 6. Spatial distribution of soil electrical conductivity in the Mnasra zone.

3.2.2.4. Exchangeable Potassium

The exchangeable potassium is a mandatory element for plant growth. The interpretation of the levels of this element is depending on the soil cationic exchange capacity (CEC). In our case, whatever the value of the CEC of the soils of the study area, the equivalent levels are very low for 84.2% of lands and moderate for 15.8% of lands. The content of the soil varies between 0.1 and 129.6 ppm (Table 4) for soil samples located in the C (P14 and P15) and B (P4) zones, respectively (Figure 7).

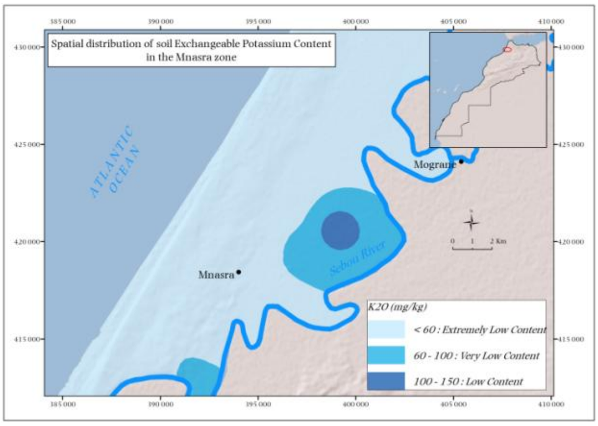

Figure 7.Spatial distribution of soil exchangeable potassium content in the Mnasra zone.

3.2.2.5. Available Phosphorus

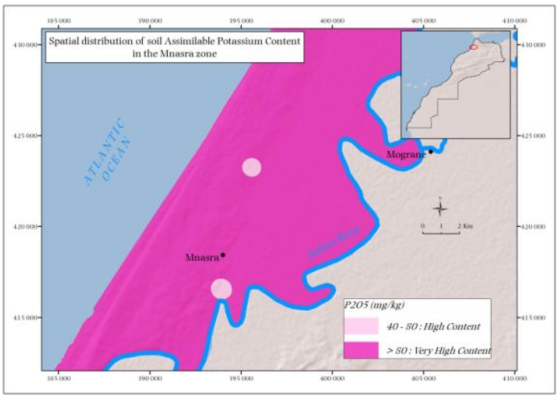

Figure 8. Spatial distribution of soil available phosphorus in the Mnasra zone.

Knowledge of the content of soil available phosphorus is necessary to optimize and maintain sustainable fertilization according to the needs of the soil and crop. The content of the soil varies between 42.4 and 282.7 ppm (Table 4). 83.3% of soils have very high levels of phosphorus (Figure 8).

3.2.2.6. Soil Alkalinity

Soil alkalinity is the result of the accumulation of soluble salts in the soil, especially Na [28]. Soil alkalinity is measured from the ESP that corresponds to the exchangeable sodium percentage. According to Badraoui and Merzouk (1994)[29], when ESP exceeds 10%, the soil becomes sodic, and the excess of exchangeable sodium leads to the deterioration of the soil structure by a dispersing effect on the colloids of the soil leading to a decrease in aeration and infiltration rate. The sodicity originates from:

- Intake of sodium from irrigation water (high SAR);
- Capillary upwelling of groundwater loaded with Na.

Table 6.Distribution of soil alkalinity classes of the M’nasra region according the FAO norms [27].

Class of soil alkalinity	ESP	Number of sites	% of sites
Non to slightly alkaline	<15	16	84.2
Light to moderately alkaline	15-30	3	15.8
Moderately to highly alkaline	30-50	0	0.0
Highly to very highly alkaline	50-70	0	0.0
Extremely highly alkaline	>70	0	0.0

The results are reported in Table 6 and on Figure 9. We note that 84.2 % of soil samples are non-alkaline and only 15.8 % can be considered either lightly or moderately alkaline, these samples are located near the Sebou River in the A zone (P7).

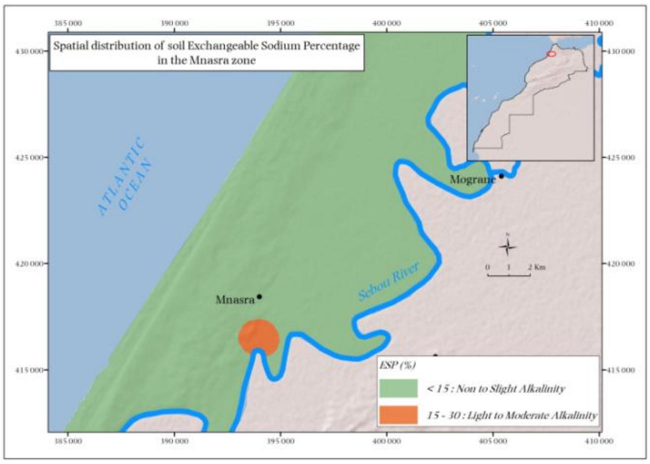

Figure 9. Spatial distribution of soil ESP in the Mnasra zone.

4. Conclusion

The study of the physic-chemical quality of water and soil of the region of M’nasra has allowed us to assess the current state of the quality of soil and water in this region particularly known for intensive agricultural activities:

Relatively average levels of soil salinity have been observed thus compromising the sustainable use of the agricultural land in the region. This phenomenon is accentuated by the irrigation waters since more than 61.1% of the waters have slight to moderate of salinization, especially in the downstream part of the region(C zone). The Sodium Adsorption Ratio (SAR) shows a minimal risk to accumulate sodium in the soil with 16.7% of the samples are slightly alkaline.
Soils have, in general (68.4%) poor to moderately poor in organic matter content , while 83.3% of soils have very high levels of phosphorus; in contrast, 84.2% of soils have very low potassium content , due mainly to the nature of the soils of the Gharb region and to the lack of control of mineral fertilization. The majority of soil samples are non-alkaline and only 15.8 % can be considered either lightly or moderately alkaline. Continuous monitoring of soil quality is required to avoid excessive degradation of this resource. The present work is a first step for the study of water and soil quality in the region of Gharb. More refined studies should be conducted in the study area affecting aspects and disciplines related to water and soil quality to better interpret the results in the context of land and water management strategy. Eventually, in order to maintain a sustainable productivity of the M'nasra's lands as well as preserving water and soil resources from degradation, we recommend to the farmers of this region to adopt best management practices, especially better control of the irrigation through water saving techniques, better reasoning of mineral fertilization as well as the frequent addition of organic amendments to the soils.

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