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Suitability of the waters of the artificial lake of Magafor irrigation (in the Far North Region of Cameroon)

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Abstract: *Irrigation water in the Maga agricultural area is a key factor in rice production. These waters come from the artificial lake of Maga. A study was carried out to study the suitability of these waters for irrigation. For this, a sampling network was chosen in order to obtain representative data on its spatial and temporal variability. Six sampling campaigns were carried out during the period from October 2017 to June 2019 on five points.Temperature, pH, EC, as well as Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, NO_3^{-}, and HCO_3^{-} were analyzed for these water samples.The percentage of sodium, the Kelly coefficient, the Permeability Index, the Sodium Absorption Ratio and the Magnesium Hazard were determined. The results show that the waters are weakly mineralized and have low salinity.The values for the percentage of sodium (Na%<65%), the permeability index (46.20 < PI < 118.67) and the sodium absorption ratio (SAR < 10 meq/L) indicate that the sampled water is of good quality for irrigation.However, the Kelly coefficient (KR >1) and the magnesium hazard (MH > 50%) reveal that the waters are poorly indicated for use in irrigation.Overall, these waters present a low risk of alkalinization and can therefore be used in irrigation for most cultivated species.*

Key words: *Water, suitability, irrigation, soil, Maga.*

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I. Introduction

Water is an essential element in life and is of great importance for many human activities.However, the increased demand for water for human activities increases the pressures on this resource (Gouaidia, 2008).Agriculture is part of human activities, consumers of large quantities of water although it is not present in large volumes in all spheres.To solve the problem of lack of water at the appropriate time of its use in agriculture, men have developed several ways of mastering this resource.The development of artificial lakes is part of the means of storing water which will be used when necessary for irrigation.However, irrigation with water rich in salts can lead to the fixation of sodium by the adsorbent complex of the soil, therefore a salinization process, with possible consequences for the properties of the soil: tendency to the dispersion of clays, to the degradation of structure, loss of permeability and asphyxiation of plants (Bauder et al., 2008; Oualid et al., 2018).Nonetheless, the intensity of the salinization process depends on the characteristics of the soil, the quality of the water used, the conditions of its use and in particular the efficiency of the drainage system.Numerous studies carried out in several countries have dealt with the quality of ground and surface water to be used in agriculture.In Algeria for example, Bouhlassa et al., (2008); Rouabhia and Djabri (2010) studied the water quality and showed that irrigation practices increase the risk of salinization to the point that more than 20% of irrigated soils are affected by a salinity problem.In Morocco, Ben Abbou et al. (2014) in their work found that the physicochemical and microbiological quality of the water used for crop irrigation in the city of Taza does not always meet the criteria for using this water for irrigation.In contrast, Oga et al. (2015) showed that 67% of the groundwater sampled in the Katiola region of Ivory Coast, is suitable for irrigation, with the exception of a few points located in the South-East.

To feed the rice fields in the locality of Maga in Cameroon, rice farmers use water from the artificial lake fitted out for this need. The diverse origins of the waters of this lake and also the eutrophication phenomenon participate in the mineralization and define the chemical facies of its waters.The aim of this work is to study the aptitude of the waters of Lake Maga for irrigation through the analysis of the risks of alkalinization and salinization of the soil from its waters.Criteria such as the percentage of sodium (Na%), the Kelly coefficient (KR), the permeability index (PI), the sodium absorption ratio (SAR) and the magnesium hazard (MH) were used to describe the power of alkalinization of the waters of Lake Maga.

II. Material And Methods

Presentation of the study area

The rice perimeter of Maga is located in the department of Mayo-Danay, Region of Far North Cameroon (10° 21'N, 15° 13'E and 10° 51N, 14° 56'E) with about 7000 ha of landscaped space (Figure 1).In this area, an estimated 120,000 people live directly from rice farming.

The climate is Sahelo-Sudanian, characterized by a long dry season that begins in October and ends in early May and a short rainy season, from June to September marked by heavy rain events.The average annual rainfall varies between 750 and 800 mm. The average annual temperature varies between 26 °C and 28 °C. The monthly average can reach 34 °C in April.The annual evapotranspiration is 1800 mm. The morphology is dominated by a flood plain (Ngounou Ngatcha et al., 2007).The soils of the zone are little developed, vertisols, and tropical ferruginous soils, hydromorphic soils and halomorphic soils (Barbery and Gavaud, 1980; Seignobos and Moukouri, 2000).The main income-generating activities are agriculture, fishing and livestock.Agriculture is dominated by the cultivation of rice, the irrigation of which is ensured by the waters of the artificial lake.It is fed by part of the discharge from the waters of Logone, by the contributions of Mayos Guerléo, Boula and Tsanaga which draw their source from the Mandara Mountains.The lake was built for an original capacity of 600 million m3 for an area of 39,000 ha.

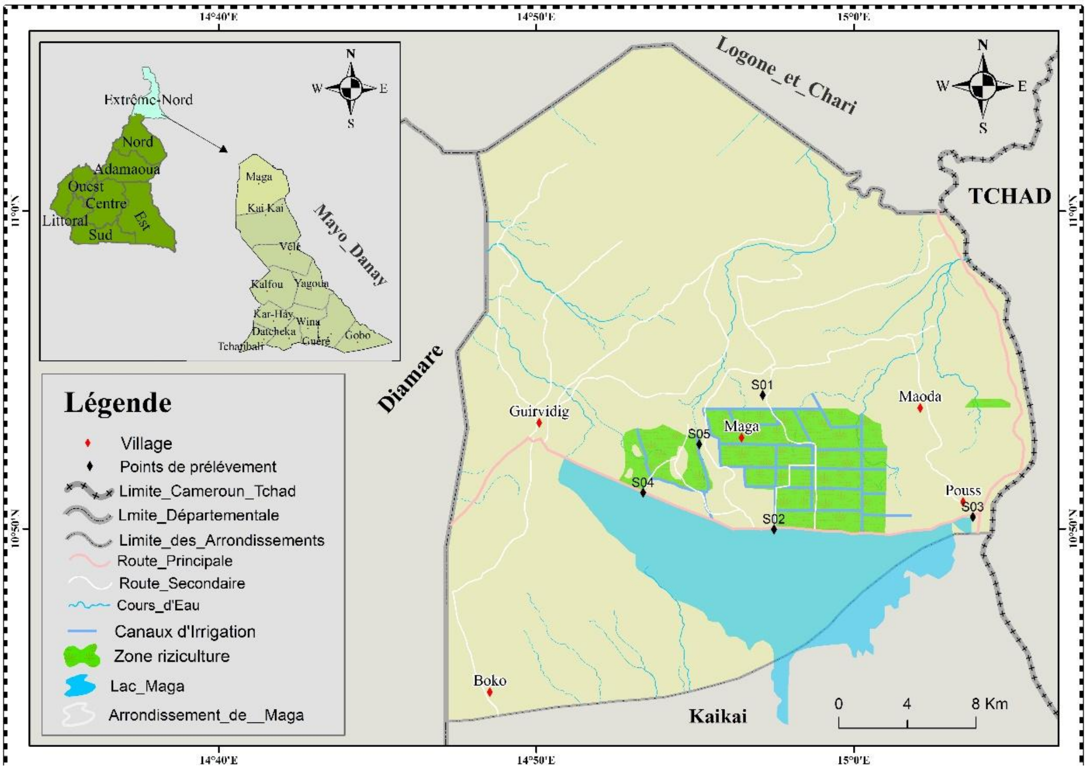

Figure no 1: Location map of the study and sampling area

Hydrochemical data

The sampling was carried out at five points, three of which are the rice paddy supply routes from the lake and two are located on drainage channels for the water exiting the rice paddies but prized for the irrigation of private rice plots as well as for market gardening.As part of this study, six sampling campaigns were carried out between October 2017 and June 2019.Temperature, pH, electrical conductivity (EC) and TDS were measured in situ with a Hanna Instruments HI 98130 multi-parameter instrument.The complete alkalimetric title was determined by field titrimetry using a 0.02N H_2SO_4 solution.Sodium (Na^+) and potassium (K^+) were measured by flame photometry.The other parameters (Ca^{2+}, Mg^{2+}, NO_3^-, Cl^- and SO_4^{2-}) were determined using a Hanna HI 83300 photometer.Statistical analysis of the data obtained was carried out with XLSTAT 2018 and Microsoft Excel software, followed by hydrochemical analysis using Diagram 6.57 software.

Assessment of potential uses of water in agriculture

There are several criteria for controlling the quality of water intended for agricultural activity.In the case of our study, we used 5 quality parameters including the percentage of sodium (Na%), the Kelly coefficient (KR), the permeability index (PI), the sodium absorption ratio (SAR)and the magnesium hazard (MH). These methods describe the alkalizing power of water.They are used in combination to assess the potential risk of soil salinization.

Percentage of sodium (Na^{+}%)

The appreciation of the percentage of sodium through the classification of Wilcox (1955) is necessary to decide on the suitability of water for irrigation.The calculation of this index is given by Todd's formula (1980):

$$Na\% = \frac{(Ca^{2+} + K^{+})}{(Ca^{2+} + Mg^{2+} + Na^{+} + K^{+})} X\ 100 \qquad (1)$$

(all concentrations are expressed in meq/L.)

Kelly coefficient (KR)

The KR is calculated using Kelly's equation (1963):

$$KR = \frac{Na^{+}}{Ca^{2+} + Mg^{2+}} \qquad (2)$$

(all concentrations are expressed in meq/L.)

Permeability Index (PI)

Sodium, calcium, magnesium and bicarbonates are used in the calculation of the PI which is obtained using the equation of Domenico and Schwartz (1990):

$$PI = \frac{Na^{+} + \sqrt{HCO_3^{-}}}{Ca^{2+} + Mg^{2+} + Na^{+}} X\ 100 \qquad (3)$$

(all concentrations are expressed in meq/L.)

Sodium Absorption Ratio (SAR)

Salt-laden water can cause Ca^{2+} to be replaced by Na^{+} and can cause soil alkalization.This risk is determined using the value of absorbable sodium which is defined by the following relationship:

$$SAR = \frac{(Na^{+} + K^{+})}{\sqrt{(Ca^{2+} + Mg^{2+})/2}} \qquad (4)$$

(all concentrations are expressed in meq/L.)

Magnesium Hazard (MH)

MH is the excessive amount of Mg^{2+} on Ca^{2+}.The MH values <50% indicate a suitability of groundwater for irrigation.In contrast, MH values> 50% indicate improper water (Lloyd and Heathcoat, 1985).HD is expressed by the following equation (Szabolcs and Darab, 1964):

$$MH = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} X\ 100 \qquad (5)$$

(all concentrations are expressed in meq/L.)

III. Results

Physical and chemical quality of water

The average minimum value of the temperature for all the campaign is 23.5±0.43 °C while the average maximum value is 31.75±2,25 °C (Table 1). These waters also have an average pH varying between 7.40±0.17 and 7.73±0.68.

The results of the electrical conductivity measurements show over all the campaign that they vary from 134 to 200 µS/cm with high standard deviations (from 22.36 to 70.36), expressing a spatial variation of the contributions in minerals.

The major cations in the waters of the study area have variable average concentrations depending on the chemical species sought.In general, the concentrations of cations are low.On all 5 samples analyzed, the average values are in the range 0.09 to 0.76 meq/L then 0.42 to 0.87 meq/L for Ca^{2+} and Mg^{2+}; from 0.82 to 1.19 meq/L then 0.01 to 0.08 meq/L of Na^{+} and K^{+} respectively (Tab. 1).

The anionic concentrations in the study area experience a significant variation in values between the different sampling points.Bicarbonates have mean values ranging from 1.69 to 2.53 meq/L with a high standard deviation (1.06) (Table 1).For chlorides the average values are from 0.01 to 0.22 meq/L with the highest values obtained in the discharge water from irrigation canals.Sulphates are weakly present with average concentrations ranging from 0.01 to 0.05 meq/L with standard deviations sometimes higher than the average.Nitrates have average concentrations in the range of 0.02 to 0.09 meq/L with minimum and maximum levels of 0.00 to 0.21 meq/L.

Table no 1: Statistical variables of the physicochemical and chemical parameters of water

	Oct-17				Feb-18				Jun-18			
Variable	**Min**	**Max**	**Aver**	**St-D**	**Min**	**Max**	**Aver**	**St-D**	**Min**	**Max**	**Aver**	**St-D**
T°C	28,04	29,02	28,67	0,43	30,90	33,90	31,75	1,44	26,90	30,80	28,65	2,00
pH	6,84	8,48	7,40	0,68	7,19	8,45	7,62	0,57	7,20	8,60	7,73	0,63
EC (µS/cm)	70,00	220,00	134,00	70,21	100,00	180,00	145,00	41,23	110,00	180,00	152,50	34,03
TDS (mg/l)	40,00	110,00	66,00	35,78	50,00	90,00	72,50	20,62	60,00	90,00	77,50	15,00
Ca^{2+} (meq/l)	0,00	1,00	0,20	0,45	0,00	2,40	0,72	1,12	0,15	2,40	0,76	1,09
Mg^{2+} (meq/l)	0,33	0,49	0,44	0,07	0,58	0,74	0,66	0,07	0,58	0,74	0,66	0,07
Na^{+} (meq/l)	0,70	1,70	0,98	0,42	0,53	0,96	0,82	0,20	0,70	1,52	1,00	0,36
K^{+} (meq/l)	0,05	0,07	0,06	0,01	0,05	0,08	0,06	0,01	0,05	0,08	0,06	0,01
Cl^{-} (meq/l)	0,00	0,03	0,01	0,02	0,03	0,18	0,09	0,07	0,03	0,18	0,09	0,07
NO_3^{-} (meq/l)	0,00	0,07	0,02	0,03	0,00	0,07	0,02	0,03	0,00	0,06	0,02	0,03
SO_4^{2-} (meq/l)	0,00	0,02	0,00	0,01	0,00	0,17	0,05	0,08	0,00	0,02	0,02	0,01
HCO_3^{-} (meq/l)	0,98	2,82	1,70	0,75	1,66	3,52	2,21	0,88	1,68	3,92	2,53	1,06

	Oct-18				Feb-19				Jun-19			
Variable	**Min**	**Max**	**Aver**	**St-D**	**Min**	**Max**	**Aver**	**St-D**	**Min**	**Max**	**Aver**	**St-D**
T°C	24,30	28,20	26,58	1,61	21,80	25,00	23,50	1,41	27,70	32,50	29,82	2,25
pH	6,89	8,14	7,32	0,51	7,25	7,66	7,41	0,17	7,03	8,52	7,61	0,57
EC (µS/cm)	110,00	190,00	144,00	34,35	130,00	190,00	160,00	22,36	140,00	320,00	200,00	70,36
TDS (mg/l)	60,00	121,00	80,20	25,89	70,00	90,00	82,00	8,37	70,00	150,00	94,00	32,09
Ca^{2+} (meq/l)	0,00	1,15	0,26	0,50	0,05	0,25	0,11	0,08	0,00	0,15	0,09	0,07
Mg^{2+} (meq/l)	0,58	1,23	0,76	0,27	0,58	1,48	0,87	0,38	0,74	1,15	0,87	0,16
Na^{+} (meq/l)	0,74	1,48	0,91	0,32	0,74	1,31	1,03	0,21	0,65	1,83	1,19	0,43
K^{+} (meq/l)	0,00	0,04	0,01	0,01	0,00	0,06	0,01	0,02	0,05	0,12	0,08	0,02
Cl^{-} (meq/l)	0,04	0,82	0,22	0,34	0,01	0,43	0,12	0,18	0,01	0,19	0,08	0,07
NO_3^{-} (meq/l)	0,00	0,21	0,06	0,09	0,00	0,08	0,04	0,04	0,00	0,16	0,09	0,06
SO_4^{2-} (meq/l)	0,00	0,02	0,01	0,01	0,00	0,08	0,02	0,04	0,00	0,02	0,02	0,01
HCO_3^{-} (meq/l)	1,40	2,08	1,69	0,34	1,36	2,34	1,72	0,38	1,45	2,42	1,88	0,38

Water facies

Analysis of the piper diagram of all the samples shows that 22 samples have a sodium and potassium bicarbonate facies and 08 samples have a calcium and magnesium bicarbonate facies (figure 2).Among the last 08 samples, we note none taken during the campaigns of October which marks the period of the rise of the waters of the lake with the great contributions by the rains and the flows of the Logone and the mayos coming from the Mandara mountains.

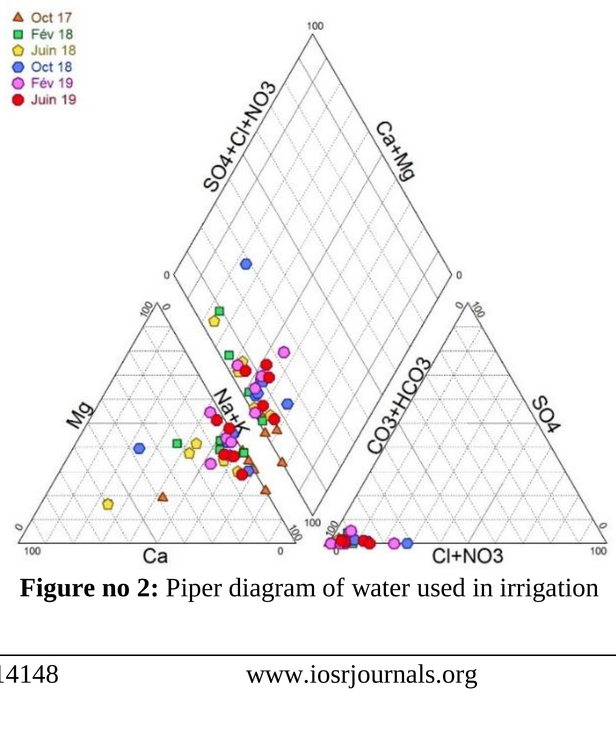

Figure no 2: Piper diagram of water used in irrigation

Water use aptitude in agriculture
Percentage of sodium (Na^{+}%)
The percentage of sodium in the sampled water varies from 1.14% to 63.50% (table 2).The highest percentages are obtained during the February and June campaigns.It therefore appears from the data obtained and projected on the Wilcox diagram that all surface waters are located in the "excellent" class, therefore favorable for use in irrigation (Figure 3).

Table no 2: Estimation of water quality parameters for irrigation

		Oct-17	Feb-18	Jun-18	Oct-18	Feb-19	Jun-19
Percentage of sodium (Na%)	S01	8,71	31,19	27,43	1,14	15,66	19,19
	S02	8,37	10,31	23,33	8,16	6,16	14,38
	S03	9,09	10,90	18,93	4,76	11,66	10,96
	S04	4,86	63,50	63,50	2,78	4,97	8,88
	S05	42,97	14,37	10,57	41,92	2,33	7,45
Kelly coefficient (KR)	S01	1,80	0,52	0,69	1,19	1,11	1,12
	S02	1,50	1,02	0,71	1,17	1,38	0,75
	S03	2,11	1,51	1,20	1,18	1,04	1,88
	S04	3,44	0,30	0,30	2,09	0,72	1,41
	S05	0,70	1,07	1,71	0,31	1,26	1,02
Permeability Index(PI)	S01	117,45	82,79	84,31	105,78	92,04	93,98
	S02	113,09	98,71	87,12	101,34	101,06	93,84
	S03	118,67	111,40	100,93	104,96	100,42	98,43
	S04	111,64	46,28	47,33	104,99	82,47	97,25
	S05	74,24	96,24	102,10	51,39	93,31	92,79
SodiumAbsorption Ratio(SAR)	S01	1,75	0,82	1,06	1,38	1,43	1,68
	S02	1,60	1,37	1,15	1,45	1,70	1,11
	S03	1,84	1,78	1,58	1,33	1,34	2,74
	S04	3,53	0,79	0,79	2,49	1,28	1,99
	S05	1,29	1,52	2,36	0,68	1,81	1,66
Magnésium Hazard (MH)	S01	100,00	65,34	65,34	100,00	69,78	83,19
	S02	100,00	88,13	73,33	92,95	86,84	94,28
	S03	100,00	100,00	79,37	92,03	92,95	84,61
	S04	100,00	21,56	21,56	92,95	93,69	89,19
	S05	33,10	83,19	83,19	51,82	95,19	100,00

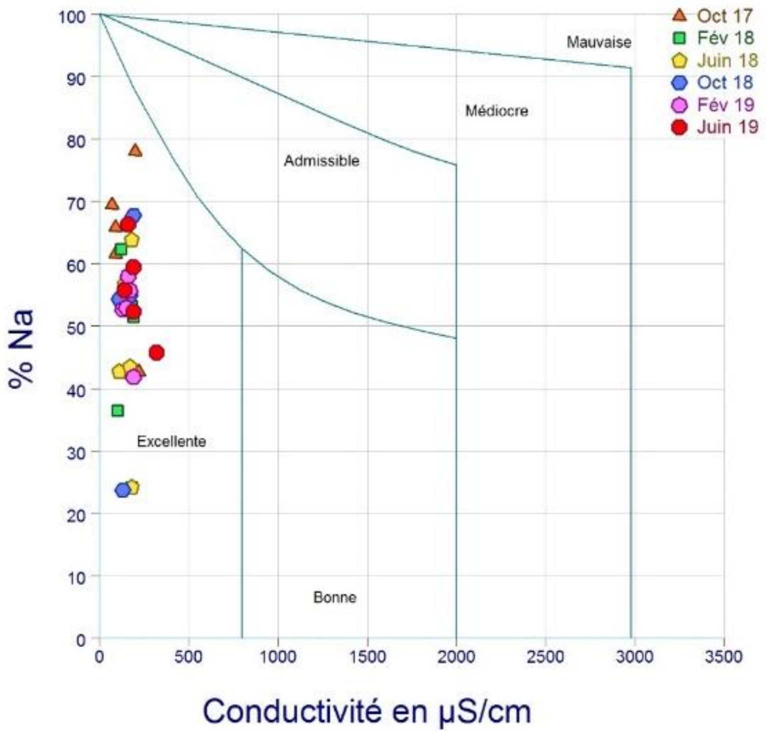

Figure no 3: Representation on the Wilcox diagram of irrigation water

Kelly coefficient (KR)

The KR values obtained range from 0.30 to 3.44 meq/L.The Kelly coefficient greater than one (KR > 1) indicates an excess of sodium in the water, therefore unsuitable for irrigation, and consequently, water with a KR less than one (KR<1) is better suited to irrigation (Narsimha and Sudarshan, 2013).The majority of the analyzed samples, 70%, has a KR > 1 (table 2) and therefore unsuitable for irrigation.

Permeability Index (PI)

The permeability index calculated for the analyzed waters ranges from 46.28 to 118.67.In the study area, only 03 of the 30 samples have PI values between 25 and 75, therefore of fair quality (table 2).These waters come from discharges from rice fields. The other samples have a PI greater than 75 resulting in good water permeability in the soil.Doneen (1964) considered that water is of good quality if its PI> 75 and it is passable if the value of PI is between 25 and 75.For PI values less than 25, water is considered unsuitable for irrigation.

Sodium Absorption Ratio (SAR)

The SAR reveals sodicity levels between 0.79 and 3.53.Water with a sodium absorption rate between 0 and 6 can generally be used on any type of soil with little problem of sodium accumulation (Couture, 2004).
The water points of the different campaigns plotted on the Richards diagram (Figure 4) were able to identify the presence of two following classes:

- Class C1S1: which represents almost all of the samples, characterizes very good quality water for irrigation;
- Class C2S1: represented by a single sample, characterizes water of good quality for irrigation and which can be used without special control for the irrigation of plants moderately tolerant to salts.

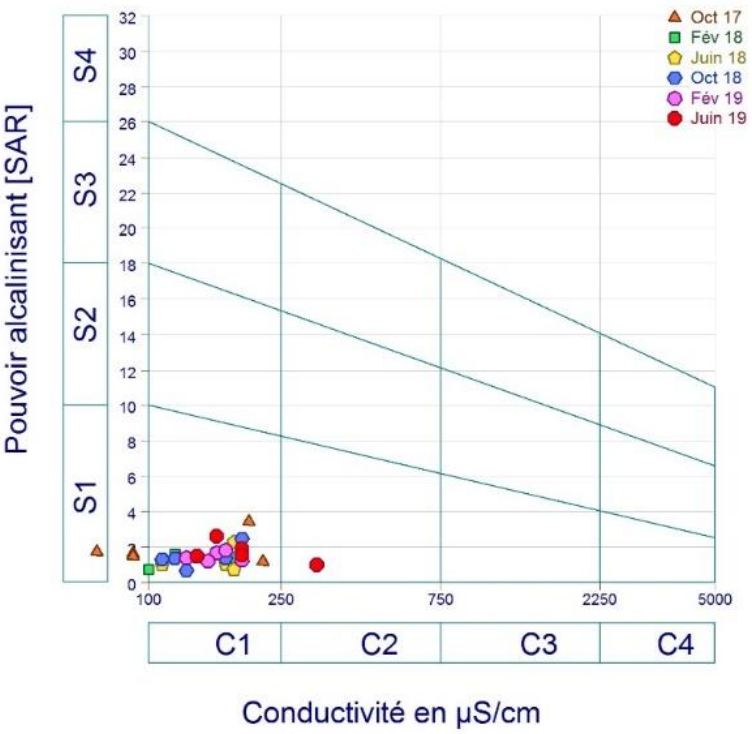

Figure no 4: Representation on the Richards diagram of irrigation water

Magnesium Hazard (MH)

In this study, the results of the MH are located between 21.56 and 100% (table 2) with 27 samples out of 30, that is to say 90% of the waters analyzed having an MH > 50% (table 2).

IV. Discussion

The results of the analyzes of the water used for irrigation in the rice perimeter of the SEMRY (Society for the Expansion and Modernization of Rice in Yagoua) II in Maga show that for the pH parameter, apart from the water from a single point of supply to the rice fields which over all six seasons has given five times pH 8 values, the other samples analyzed can be used in irrigation without risk of alkalinization. According to Peterson (1999), the pH of water used for crop irrigation should be between 6 and 7 because at these values the solubility of most microelements is optimal.Also, the CE values obtained show that all of our samples are non-saline because all these values are less than 250 µS/cm (USSLS, 1954).It should be noted that sparingly salty waters with an electrical conductivity of less than 200 µS/cm have a strong tendency to rapidly mobilize calcium from the soil, which favors the dispersion of particles and the obturation of porous spaces (Ayers and Westcot, 1988).

In the study area, the waters belong to two chemical facies in which there is a dominance of weak acids with for the bicarbonate calcium and magnesium facies a dominance of alkaline earths then a dominance of alkalines over alkaline earths for the sodium carbonate and potassium facies.Thus, these waters are enriched in sodium and potassium in terms of cations while bicarbonates remain the dominant anion.However, these chemical elements are present in these waters in tolerable concentrations for use in irrigation.The low concentrations of cations obtained in irrigation water have the advantage of limiting the supply of elements to the soil that can contribute to their alkalization.The appreciation of the percentage of sodium through the classification of Wilcox (1955) is necessary to decide on the suitability of water for irrigation.Wilcox recommends taking into account the conductivity, i.e. the salinity of the water, the danger of alkalinization of the soil and the concentrations of elements harmful to plants, in particular boron.Indeed, the very high contents of salts, sodium and boron are harmful to plants.In this study, only electrical conductivity and sodium are taken into account, the boron not having been analyzed.The results obtained indicate that these waters are favorable for use in irrigation.These results are similar to those obtained by Oi Adjiri et al. (2020) in the natural spring waters of Daloa and Zoukougbeu in Ivory Coast. The water withdrawn during the months of October is the most favorable with the lowest percentages which are explained by the effect of water dilution after increase in the water level in the lake following the various inputs by the rains and the runoff.If for the percentage of sodium, the level of sodium in water is admissible for irrigation, it should be noted that in agriculture the degree of permeability of a soil greatly influences the yield.This permeability depends on several factors including the total concentration of water, the amount of sodium, the concentration of bicarbonates and the nature of the soil itself (Younsi, 2001; Debieche, 2002).These parameters that are used in calculating the PI have the ability to influence the permeability of a soil by modifying its physical and chemical properties.The presence, for example, of sodium in the soil increases the volume of the clay particles, thus causing an obstruction of the pores between the particles.Despite the fairly high rate of bicarbonates, our waters have a low capacity to be able to influence the permeability of the soils because of the low sodium contents obtained and a low to average total mineralization.These low concentrations will lead to a good permeability which allows a good supply of water to the crop, making it much easier to cultivate on rice plots.Ngounou (1993) 's work in this area already highlighted the basic exchange phenomenon which occurs from the contact of surface water with the surface soil layers.This basic exchange phenomenon results in the substitution of the alkaline earths (Ca and Mg) of water with the alkalines (Na and K) of the terrains crossed, thus enriching the soil with alkaline earths and groundwater. in alkalis, phenomenon favoring the permeability of these soils.

The good quality of the waters of Lake Maga is also confirmed by the results of the SAR.All the waters studied have a SAR of less than 6 and are thus mainly represented in classes C1S1 and C2S1 which correspond respectively to water of low and medium salinity.These waters present a low danger of soil alkalinization.These results are in agreement with those of Soro (2002) and Oga et al., (2015) obtained on groundwater used for irrigation in the regions of Grand Lahou and Katiola in Ivory Coast respectively. When the concentration of Na^+ ions in the soluble state in the soil becomes high, they most frequently replace the Ca^{2+} cations in the absorbent complex.Nonetheless, salt-laden water can cause this action as mentioned above.However, the geology of the study area reveals the predominance of calcium and magnesium over sodium in soils (Leumbe, et al., 2015), a phenomenon favored by the basic exchange process.

However, an analysis of the results obtained after calculating the KR shows that the water in the area is not very suitable for irrigation.It is recognized that when sodium is found in large quantities, it can replace the alkaline-earth ions of the clays and deflocculate them, causing the modification of the soil structure. The size of the soil pores decreases by swelling of the clay particles, which in the study area have a high proportion (Barbery and Gavaud, 1980), which can cause the impermeability of the soil.Likewise, the dispersion of colloids causes the finer particles to settle in the pores of the soil and to clog the surface layers; which makes the soil hard, compact and suffocating for plants.The results of the MH parameter also show that with the exception of three samples out of the 30 analyzed, the waters of Lake Maga are not recommended for irrigation because of its enrichment in Mg^{2+}. Generally, there is a balance between magnesium (Mg^{2+}) and calcium (Ca^{2+}) in water.The excess of Mg^{2+} affects the quality of the soil, leading to its alkalization, then negatively affecting agricultural yields (Rao et al., 2012).In the case where the content of Ca^{2+} is lower than that of Mg^{2+}, the latter will behave in the same way as Na^+ and thus degrade the structure of the soil.

V. Conclusion

This study assessed the suitability of the waters of the artificial Lake Maga in the Far North region of Cameroon for irrigation.At the end of this study, it should be noted that the majority of the water analyzed from the lake is of suitable quality for irrigation because there is no risk of alkalinization of the soil.These waters are weakly mineralized with EC values all less than 250 µS/cm which do not favor the fixation of sodium on the adsorbent complex of the soil.Studying the influence of chemical elements that can influence soil permeability shows that 90% of our samples have an acceptable permeability index for irrigation.The basic exchange mechanism which occurs in contact with surface water with the soil layers leads to a substitution of the alkaline earths of the irrigation water with the alkalines of the lands crossed, favorising the permeability of the soils.

References

[1]. Ayers R.S. et Westcot D.W., 1988. La qualité de l'eau en agriculture. Bulletin FAO d'irrigation et de drainage. 29 Rév. 1, 165 p.

[2]. Barbery J., Gavaud M., 1980. Notice explicative de la Carte Pédologique du Cameroun feuille Bogo-Pouss à 1/100 000.ORSTOM-IRAF-ONAREST, Paris no 88, 58 p.

[3]. Bauder, J. W., Bauder T. A., Waskom R. M., Scherer T. F., (2008). Assessing the suitability of water (quality) for irrigation – Salinity and Sodium.

[4]. Ben Abbou M., Fadil1 F. et El Haji M. (2014). Évaluation de la qualité des cours d'eau de la ville de Taza utilisés dans l'irrigation des cultures maraîchères (Maroc). *Journal of Applied Biosciences* n°77, pp. 6462-6473.

[5]. Bouhlassa S., Alechcheikh C. et Kabiri L. (2008). Origine de la minéralisation et de la détérioration de la qualité des eaux souterraines de la nappe phréatique du Quaternaire du bassin versant de Rheris (Errachidia, Maroc). *Sécheresse*, vol. 19, n° 1, pp. 67-75.

[6]. Couture I. (2004). Analyse d'eau pour fin d'irrigation MAPAQ. Montérégie-Est AGRI-VISION 2003-2004, 8 p.

[7]. Debieche T.H. (2002). Evolution de la qualité des eaux (salinité, azote et métaux lourds) sous l'effet de la pollution saline, agricole et industrielle. Thèse de doctorat. Univ. de franche comté. 199p.

[8]. Domenico P.A. and Schwartz F.W., 1990. Physical and chemical hydrogeology. *Wiley*, New York, pp 410–420.

[9]. Gouaidia L. (2008). Influence de la lithologie et des conditions climatiques sur la variation des paramètres physico-chimiques des eaux souterraines d'une nappe en zone semi-aride, cas de la nappe de Meskiana, Nord-Est algérien. Thèse de Doctorat en sciences, Université d'Annaba, Algérie, 129 p.

[10]. Kelly W.P. (1963). Use of saline irrigation water. *soil science*, 95 (4), pp. 355-391

[11]. Leumbe L. O., Bitom D., Mamdem L., Tiki D. et Ibrahim A., 2015. Cartographie des zones à risques d'inondation en zone soudano-sahélienne : cas de Maga et ses environs dans la région de l'extrême-nord Cameroun. *Afrique SCIENCE11(3) pp.45 – 61.*

[12]. Lloyd J.W. et Heathcoat J.A., 1985. Natural inorganic hydrochemistry in relation to groundwater : an introduction. *Oxford University Press*, New York, 296 p.

[13]. Oga M. S., Gnamba F. M., Adiaffi B., Soro T., Oulai K. and Biémi J. (2015). Aptitude of Groundwaters for Irrigation in Katiola Area. *Asian Review of Environmental and Earth*, Vol. 2, N° 3, pp. 54-60.

[14]. Oi Adjiri A., Assoma T.V., Soro G., Aka N., Bengaly I. et Soro N., (2020). Évaluation des aptitudes d'usages des eaux de sources naturelles dans l'agriculture à partir de techniques hydrochimiques : cas de celles des départements de Daloa et Zoukougbeu, Côte d'Ivoire. *Afrique SCIENCE* 16(1) : 204 - 217

[15]. Oualid B., Azeddine M., Zeineddine N., Benoit L., (2018) : Hydrogéochimie, et variations spatio-temporelles de la qualité des eaux souterraines dans le bassin versant de Boumerzoug -Nord Est Algérie. *Sciences & Technologie* D-N°47 : 31-41.

[16]. Peterson, H.G. Water quality and Micro-irrigation for horticulture. Agriculture et Agroalimentaire Canada (1999).

[17]. Rao NS, Rao PS, Reddy GV, Nagamani M, Vidyasagar G, Satyanarayana NLVV. 2012. Chemical characteristics of groundwater and assessment of groundwater quality in Varaha River basin, Visakhapatnam district, Andhra Pradesh, India. *Environmental Monitoring and Assessment*184 : 5189–5214

[18]. Rouabhia A.E.K. et Djabri L. (2010). L'irrigation et le risque de pollution saline. Exemple des eaux souterraines de l'aquifère miocène de la plaine d'El Ma Labiod. *Larhyss Journal*, n° 8, p. 55-67.

[19]. Roupsard M., 1984. La riziculture irriguée dans les plaines de l'Extrême-Nord du Cameroun. *Rev. de Géogr. du Cameroun*, vol. IV, n° 2 : 47-71

[20]. Seignobos C. et Moukouri H. K. Potentialités des sols et terroirs agricoles : Atlas de la Province de l'Extrême-Nord Cameroun (2000), pp-3.

[21]. Soro N. (2002). Hydrochimie et Géochimie isotopique des eaux souterraines du degré carré de Grand-Lahou et ses environs (Sud-Ouest de la Côte d'Ivoire). Implications hydrologiques et hydrogéologiques. Thèse de Doctorat d'Etat ès Sciences Naturelles, Université de Cocody, 256 p.

[22]. Szabolcs I and Darab C., 1964. The influence of irrigation water of high sodium carbonate content of soils. *In* : *8th internat. Congr. ISSS*, Trans, vol. 2, pp 803– 812.

[23]. Todd D., 1980. Groundwater, *2nd ed.*. *Wiley*, New York, 535p.

[24]. U.S.S.L.S. (United State Salinity Laboratory Staff) : Diagnosis and improvement of saline and alkali soils. US Department of Agriculture, Handbook n°60, U. S. Gov. Print. Office, Washington DC, (1954).

[25]. Wilcox L. V., 1955. Classification and Use of Irrigation Water, Washington : *US Department of Agriculture*. Circular, n° 969, 19 p.

[26]. Younsi A. (2001). Méthodologie de mise en évidence des mécanismes de salures des eaux souterraines côtières en zone semi-aride irriguée. Chaouia côtière, Maroc. Thèse de doctorat d'état, Université Chouaib Doukkali, El Jadida, Maroc.

Aguiza Abaï Emmanuel. et. al. "Suitability of the waters of the artificial lake of Magafor irrigation (in the Far North Region of Cameroon)." *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)*, 14(5), (2020): pp 41-48.