Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

p-ISSN: 0972-6268
(Print copies up to 2016)
e-ISSN: 2395-3454

Vol. 23 | No. 1 | pp. 331-339 | 2024

Original Research Paper

https://doi.org/10.46488/NEPT.2024.v23i01.028

Open Access Journal

Water Resource Impacts of Irrigation: The Case of the Main Irrigation Canal from the M'Pourie Plain to Rosso in Mauritania

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Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 26-07-2023
Revised: 09-09-2023
Accepted: 10-09-2023

Key Words:
Water resource
Irrigation water quality
Irrigation
M'Pourie plain

ABSTRACT

An important factor in determining agricultural production is the availability of irrigation water in the main canal of the M'Pourie plain. This factor affects both the intensification of crops and the size of the irrigation areas. The main Senegal River canal in Rosso, Mauritania, runs across the Plaine of M'Pourie. This study aims to assess the physicochemical quality of the water used for irrigation and agriculture in the main irrigation canal on the M'Pourie plain. The measurements were made from 2021 to 2022, and the following physical and chemical parameters were monitored: pH, temperature, electrical conductivity, salt content, calcium, magnesium, sodium, and potassium; ammonium bicarbonate; chloride; nitrite; nitrate; nitrogen; sulfate; and sodium adsorption ratio (SAR). These measurements were analyzed using volumetric, spectroscopic, and spectrophotometric methods. After conducting statistical analysis and comparing the results with Moroccan quality standards for surface water utilized in irrigation, it has been discovered that the average pH value is 7.51, indicating a neutral state. However, the average nitrite and ammonium values exceed Moroccan standards at 5.16 $mg.L^{-1}$ and 0.41 $mg.L^{-1}$, respectively. The water's low mineralization is attributed to its low electrical conductivity, with an average of 52.2 $\mu S.cm^{-1}$. Based on the analysis of the Senegal River water used for irrigation in the M'Pourie plain, it has been determined that its sodium adsorption ratio and electrical conductivity classify it as belonging to class C1S1. This indicates that the water has low salinity and is excellent for irrigation, with a low risk of alkalinization.

INTRODUCTION

In many countries, the water demand now surpasses the available supply. As the world's population continues to increase, natural water shortages are becoming more frequent (Gu et al. 2019, Hussain et al. 2019). Studies indicate that by 2025, an estimated 3.5 million people worldwide may face water shortages (Guterres 2017). As a result, researchers are exploring unconventional water resources to alleviate this issue. Irrigation is identified as the main consumer of freshwater, accounting for around 80% of total freshwater use for agricultural land (Rizzo et al. 2020). It is forecast to increase by a further 15% by 2030 (Guterres 2017, World Bank 2017), which will exacerbate water crises in regions already facing shortages, such as North Africa and the Middle East, in the coming decades, a proportion of over 40% of the world's population is expected to face water stress or water scarcity, which will have a significant impact on water security (Elgallal et al. 2016). On May 25, 2020, the European Commission published a new regulation establishing minimum requirements for the reuse of water for agricultural irrigation purposes, which came into force. However, the corresponding new guidelines will be implemented from June 26, 2023, and will facilitate water reuse within the European Union (Becerra-Castro et al. 2015). According to recent statistics, agriculture consumes the largest share of water compared to industry and domestic needs (Becerra-Castro et al. 2015). It uses more than 70% of total withdrawals.

Mauritania, a Sahelian country, experiences frequent droughts and unpredictable weather patterns. It receives minimal rainfall and has a high rate of sunshine, resulting in a scarcity of water resources. Despite these challenges, the Senegal River is a vital source of freshwater for Mauritania. The river is extensively used for drinking water and irrigation of farms along both banks. It is a crucial natural resource for the country and the sub-region, playing a significant role in socio-economic development. Unfortunately, due to population growth, human activities, and the impact of climate change in this region, the quality of the river's water is deteriorating (World Bank 2017). The issue of water quality in the Senegal River is a crucial social, economic, political, and scientific concern regarding irrigation development. The primary source of water for irrigation in Mauritania is the river's runoff. The goal of this study is to monitor the physical and chemical quality of the Senegal River's water and evaluate its appropriateness for irrigation purposes.

Additionally, this research aims to assess the impact of the river's water on the primary irrigation canal of the M'Pourie plain in Rosso, Mauritania. We analyzed various parameters, including Temperature, pH, Conductivity, Dissolved Salt Content, Chloride, Sulfate, Bicarbonates, Calcium, Magnesium, Sodium, Potassium, Ammonium, Nitrogen, Nitrate, and Nitrite. Additionally, our study aims to estimate the possible effects of the primary irrigation canal on the water resources of the M'Pourie plain in Rosso, Mauritania.

MATERIALS AND METHODS

Study Area

The study was conducted at the M'Pourie plain in Rosso (Trarza), which is the primary agricultural zone in Mauritania. It was established in the 1980s as a pilot farm and covers an expansive 1,500 hectares. The plain features a machinery department and a pumping station from the Senegal River valley, and it's divided into three brigades. The cooperatives manage 850 hectares, while the remaining area covers 1,500 hectares. The Trarza region, where the plain is located, is between latitudes 16°30' and 18°30' and longitudes 14° and 16°, with a total surface area of 33,000 km². The region is renowned for its intensive agricultural activity. To gather water samples, we selected nine sites along the edge of the primary canal of the M'Pourie plain.

Sampling

During the 2021-2022 period, sampling was carried out at nine sites along the main M'Pourie canal, with four sites in the middle of the canal (SP, CP1, CP2, CP3), four on the left bank (CST3-1-1, CS3-2-1, CS3-1, and (CS1), and one site on the right bank (CS2-1). Sampling sites were l The sampling sites, which were selected due to their proximity to pollution sources and accessibility, were situated 100 meters apart from each other. They were named as follows: Canal Principal1 (CP1), Canal Secondaire1 (CS1), Canal Principal2 (CP2), Canal Secondaire2 (CS2), Canal Principal3 (CP3), Canal Secondaire 3-1 (CS3-1), Canal Secondaire3-2 (CS3-2), Canal Secondaire Tertiaire 3-1 (CST3-1), and Station de Pompage (SP). Samples were collected in one-liter plastic bottles and kept at a temperature of 4 degrees Celsius. The analyses were conducted at the laboratory of the Water-Pollution-Environment unit, located at the

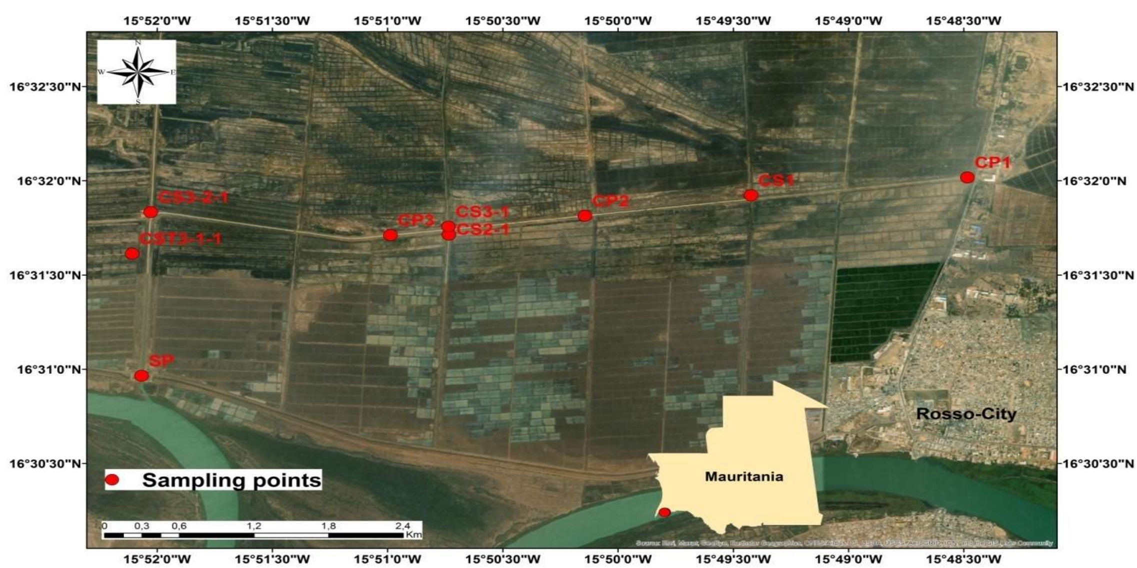

Fig. 1: Sampling sites for the main irrigation canal on the M'Pourie plain.

Table 1: Overview of physico-chemical parameters at various sites.

Parameters	CP1	CS1	CP2	CS2	CP3	CS3-1	CS3-2	CS3T-1	SP	Average	STANDARDS	
											MOROCCO	FAO
Temperature (°C)	29.5	29.3	29.1	29.1	29.1	29.1	29.1	29.1	29.1	29.1	35°C	--
pH	8.40	7.71	7.66	7.42	7.37	7.45	7.27	6.90	7.41	7.51	6.5 -8.4	6.5 -8.4
Conductivity µS/cm	50	60	50	50	50	50	50	60	50	52,22	8700	< 750
Total dissolved salt [mg.L^{-1}]	25	30	25	25	25	25	25	30	25	26,11	--	--
Calcium [mg.L^{-1}]	8.81	8.81	3.20	4.80	6.41	4.80	7.21	7.21	7.21	6.49	--	--
Magnesium [mg.L^{-1}]	2.43	3.40	4.80	3.88	2.91	4.86	1.91	2.91	2.43	3.28	--	--
Sodium [mg.L^{-1}]	18	19	18	21	20	21	18	21	19	17,44	69	--
Potassium [mg.L^{-1}]	2	4	5	6	5	2	4	5	5	4,22	--	--
Ammonium [mg.L^{-1}]	0.26	0.35	0.49	0.17	0.93	0.18	0.24	0.78	0.32	0.41	--	--
Nitrite [mg.L^{-1}]	2.64	4.12	6.43	1.15	13.69	1.32	2.31	11.22	3.63	5.16	--	--
Nitrate [mg.L^{-1}]	3.52	5.50	8.58	1.54	18.26	1.76	3.08	14.96	4.84	6.88	50	5.0 – 30
Nitrogen [mg.L^{-1}]	0.80	1.25	1.95	0.35	4.15	0.40	0.70	3.40	1.10	1.56	--	--
Sulfate [mg.L^{-1}]	38	17	37	8	90	20	14	69	4	33	250	--
Bicarbonates [mg.L^{-1}]	67.10	61.00	61.00	67.10	79.30	54.90	54.90	61.00	42.70	61.00	518	< 91,5
Chloride [mg.L^{-1}])	31.95	28.40	24.85	24.85	28.40	28.40	28.40	28.40	28.4	28.01	350	< 142

Faculty of Science and Technology of the University of Nouakchott.

Analysis Methods

After collecting the samples, we used a HANNA HI 9024 pH meter to measure temperature and pH levels. The HANNA HI 8733 conductivity meter is used to measure electrical conductivity (EC). To determine the levels of nitrates (NO_3^-), nitrites (NO_2^-), ammonium (NH_4^+), and sulfates (SO_4^{2-}), we utilize a UV-visible spectrophotometer (WEG 7100). Meanwhile, the presence of calcium (Ca^{2+}), magnesium (Mg^{2+}), chloride (Cl^-), and bicarbonates (HCO_3^-) are determined through the volumetric method in the presence of selective media. Additionally, we quantify the levels of sodium (Na^+) and potassium (K^+) using a Corning-type flame photometer. Lastly, the sodium adsorption ratio (SAR) is calculated using the following formula: SAR= $[Na^+]/\{(Ca^{++}+Mg^{++})/2\}^{1/2}$, where the concentrations of Na^+, Ca^{2+}, and Mg^{2+} ions are expressed in meq.L^{-1}.

RESULTS AND DISCUSSION

Assessment of Water Quality in the Main Irrigation Canal on the M'Pourie Plain

A comparison was made between the quality parameters of irrigation water at M'Pourie, measured at nine different sampling sites, and other studies on surface water quality used for irrigation. The study evaluated 15 parameters of M'Pourie irrigation water from nine distinct locations. Table 1 displays the results obtained for each physico-chemical parameter, which were compared to Moroccan and FAO standards. The analysis of physico-chemical parameters varied across the different samples tested.

pH and Temperature Evaluations

The pH values observed across different samples, ranging from 6.9 to 8.40 (as depicted in Fig. 1), adhere to the Moroccan regulations for ensuring the quality of water used for irrigation. The pH levels being close to neutral are advantageous for irrigation purposes. Notably, similar pH results have been reported by (Kahimba et al. 2016, N'diaye et al. 2014, Nsiala Kimfuta 2012).

Furthermore, the mean temperature value recorded in Fig. 1 is 29.1°C, which is consistent with the Moroccan regulations for water quality intended for irrigation. This temperature value is in line with what was reported by (Nsiala Kimfuta 2012).

Evaluation of Conductivity and TDS

Fig. 2 displays the conductivity values, with the maximum value being 60µS.cm^{-1} and the minimum value being 50 µS.cm^{-1}. These findings are comparable to those discovered by (Nsiala Kimfuta 2012). However, our results are lower than those obtained by (Kahimba et al. 2016). These observations indicate that the Senegal River water utilized for irrigation has poor mineralization. The average TDS value (Fig. 3) of 26.11 mg.L^{-1} aligns with Moroccan and FAO standards. These values are also similar to those found by (Nsiala Kimfuta 2012), indicating that the Senegal River water used for irrigation has relatively low mineralization.

Chloride, Sulfate and Bicarbonate Evaluations

Fig. 4 displays the levels of sulfate, chloride, and bicarbonate. The research conducted on nine sites indicates that the sulfate and bicarbonate levels adhere to the regulations set by Morocco. The average sulfate value is 33 mg.L^{-1}, which aligns with the findings of (Akil et al. 2014). Moreover, the average chloride value is 28.01 mg.L^{-1}, consistent with the standards set by Moroccan and FAO. These outcomes are comparable to (N'diaye et al. 2014) research.

Calcium and Magnesium Evaluations

The calcium concentration values displayed in Fig. 5 are 6.49 mg.L^{-1}, which is unacceptable. Good-quality irrigation water should contain calcium levels ranging from 20 to 400 mg.L^{-1}, as per (Rodier 2009). It is worth noting that the magnesium value of 3.28 mg.L^{-1} is lower than that obtained by (Nsiala Kimfuta 2012).

Sodium and Potassium Evaluations

According to Fig. 6, it can be observed that the irrigation water sampling sites exhibit an average sodium level of 17.44 mg.L^{-1} and an average potassium level of 4.22 mg.L^{-1}. There appear to be no errors in the data presented.

Evaluations of Nitrogen Elements

The water samples taken from various watercourses showed significant concentrations of nitrogenous elements. These concentrations were found to exceed the quality standards set by Morocco for irrigation water, as shown in Fig. 7. Table 1 reveals that the nitrite concentrations ranged from 1.15 mg.L^{-1} to 13.69 mg/L^{-1} across the nine sampled sites, exceeding the Moroccan standard limits. Our findings align with those of Mounjid et al. (2014) and are higher than those of Akatumbila et al. (2016). Nitrate levels were within

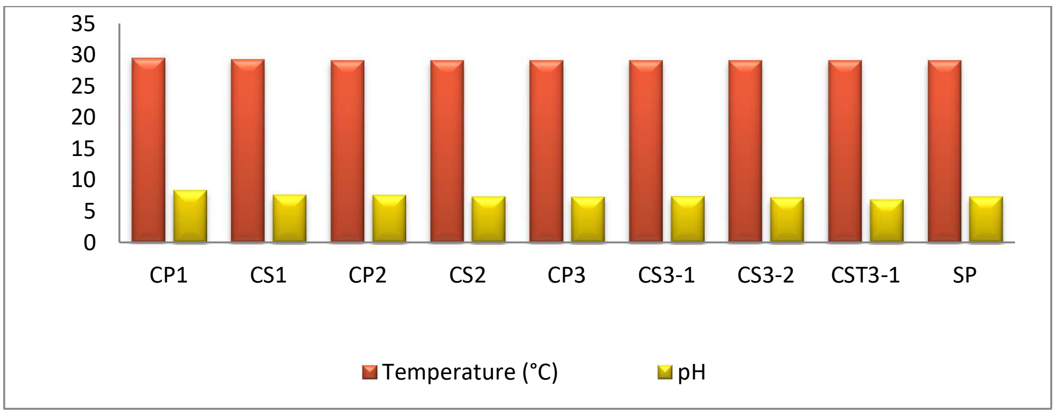

Fig. 1: pH and temperature evaluations.

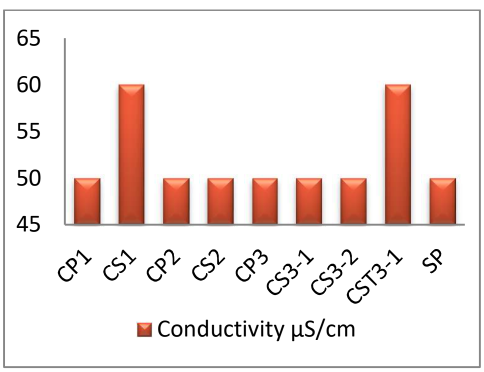

Fig. 2: Evaluation of conductivity.

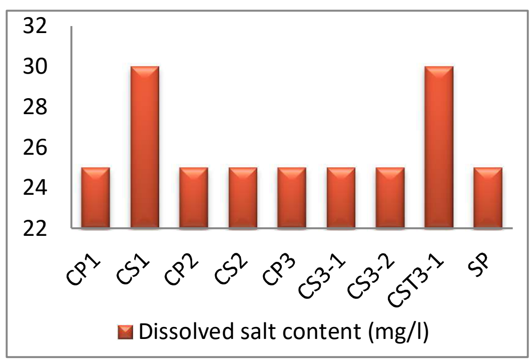

Fig. 3: Evaluation of TDS.

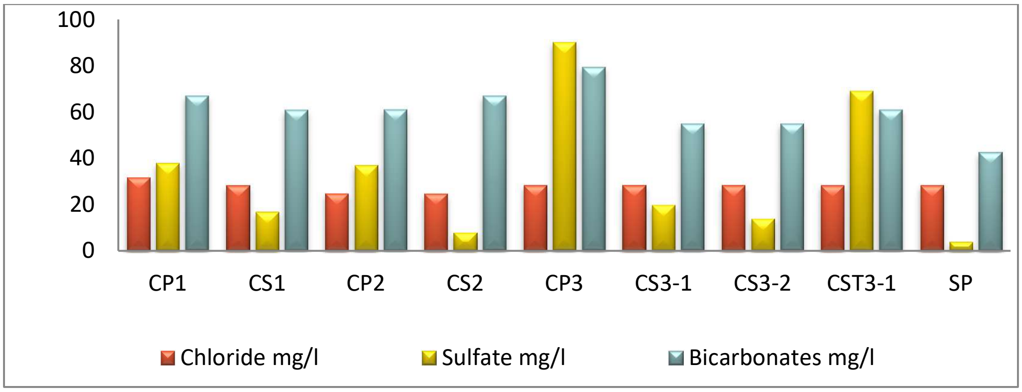

Fig. 4: Chloride, sulfate and bicarbonate values.

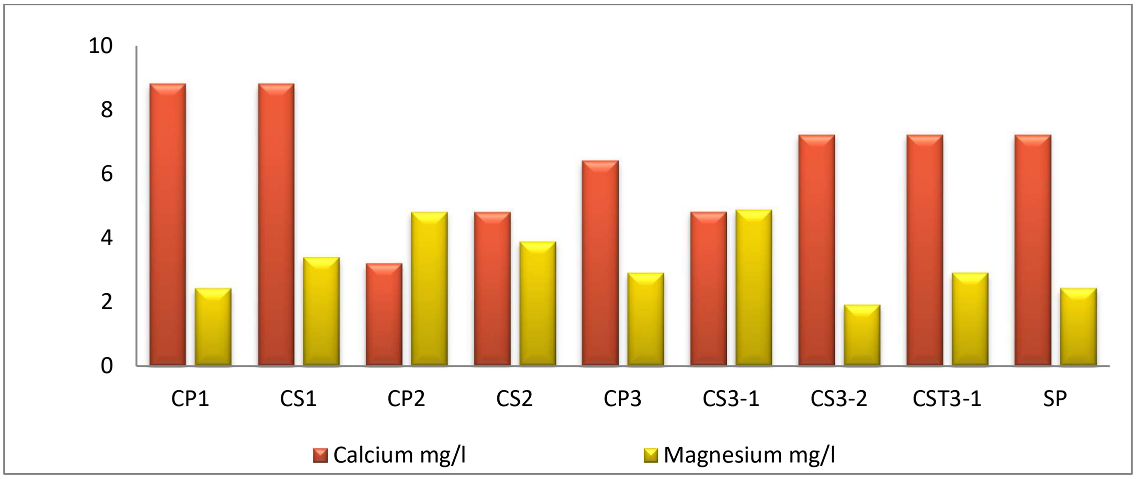

Fig. 5: Calcium and magnesium evaluations.

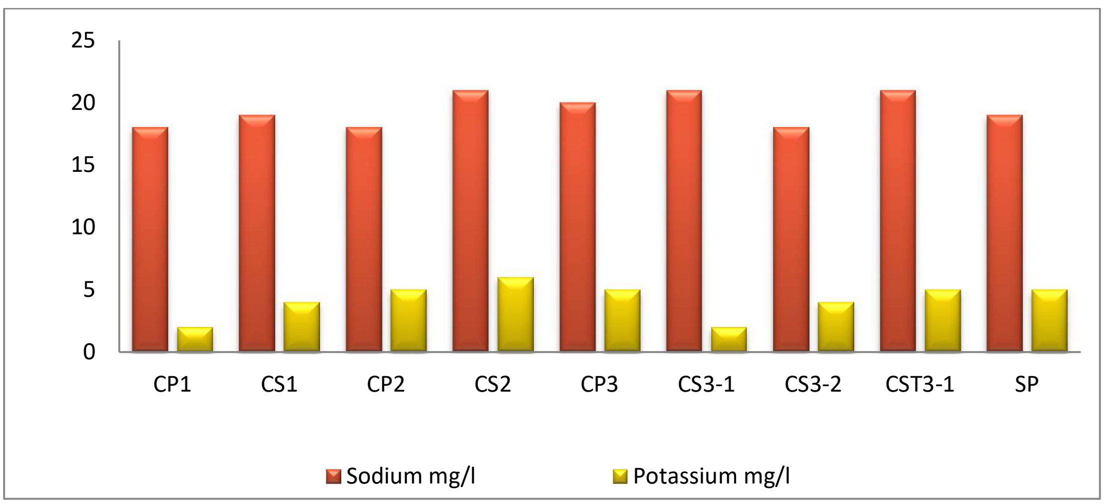

Fig. 6: Sodium and potassium evaluations.

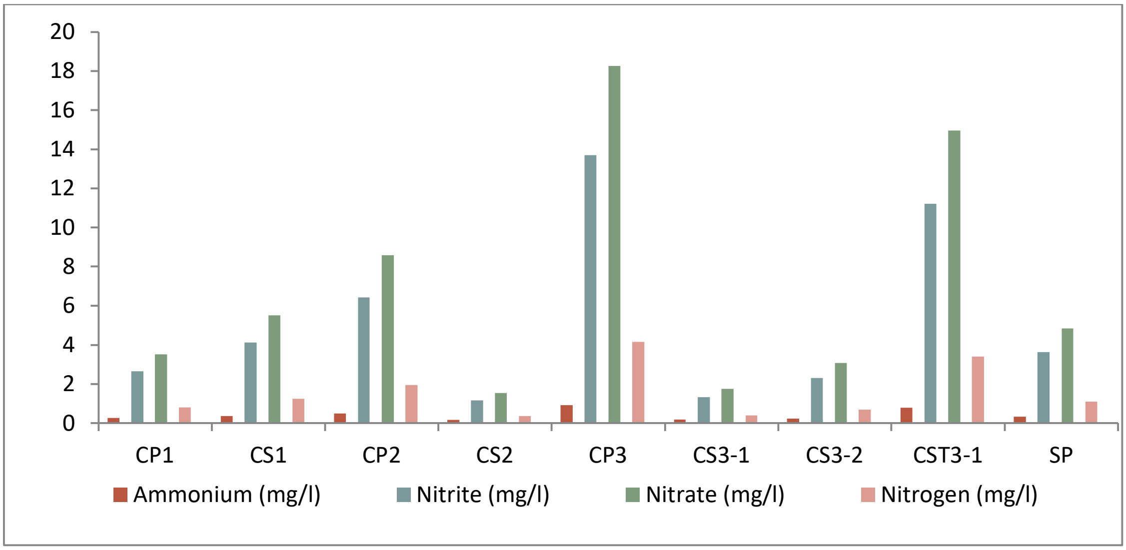

Fig. 7: Evaluations of azotic elements (ammonium, nitrites, nitrates, and nitrogen).

Table 2: The physical-chemical irrigation parameters in meq.L^{-1}.

Parameters	Symbol	Unit	CP1	CS1	CP2	CS2	CP3	CS3-1	CS3-2	CS3T-1	SP
Conductivity	CE	µS.cm^{-1}	50	60	50	50	50	50	50	60	50
Calcium	Ca^{2+}	Méq.L^{-1}	0.44	0.44	0.16	0.24	0.32	0.24	0.36	0.36	0.36
Magnesium	Mg^{2+}	méq.L^{-1}	0.19	0.27	0.38	0.31	0.23	0.38	0.15	0.23	0.19
Sodium	Na^{+}	méq.L^{-1}	1.56	1.65	1.56	1.83	1.74	1.83	1.56	1.86	1.65
Potassium	K^{+}	méq.L^{-1}	0.05	0.10	0.12	0.15	0.12	0.05	0.10	0.12	0.12
Sodium Adsorption Ratio	SAR	-------	3.92	4.16	3.92	4.61	4.38	4.61	3.92	4.68	4.16

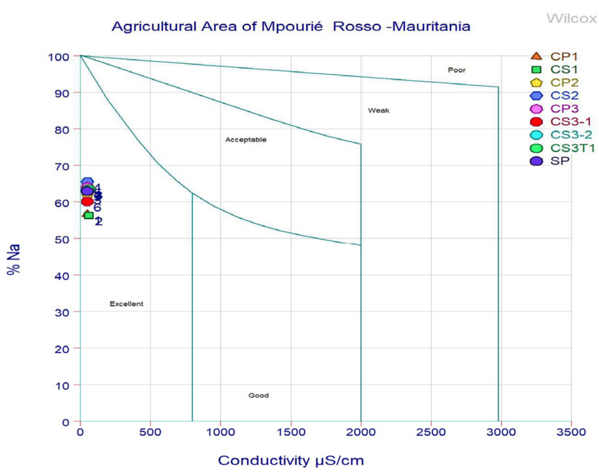

Fig. 8: Evaluation of the salinity of M'Pourie waters.

Moroccan standards, but the values obtained were higher than those found by Pwema (2014). The ammonium levels obtained across the nine sites were similar to those found by Diallo et al. (2011), but our results were higher than those obtained by Akatumbila et al. (2016).

Water Quality in the Main Canal of the M'Pourie Plain for Irrigation Purposes

When analyzing irrigation water, temperature (25 degrees) and SAR are two crucial variables to consider. The classification system developed by Scientist Richards is widely used for assessing salinity-alkalinity risks, with 16 classes available. However, it should be noted that this method alone does not provide information on the risk of salinization or sodification. To assess these risks, it's important to consider electrical conductivity and SAR, both of which are useful indicators for soil salinization and alkalinization.

The M'Pourie plain's irrigation water has a salt adsorption ratio (SAR) ranging from 3.92 to 4.68, with an average of 4.26 (Table 2). All samples previously tested had sodium adsorption ratios below 10, indicating that there is no accumulation of sodium (Goula et al. 2007) (Fig. 8).

The US Salinity Laboratory has created a quality scale for irrigation water to mitigate its negative impact on soil and plants. The scale is based on electrical conductivity and SAR.

Irrigation Water Classifications in Relation to Conductivity and SAR

The determination of the chemical quality of water for its use in irrigation is based on the knowledge of the chemical characteristics of several variables particularly salinity and the sodium adsorption ratio (SAR) to determine the suitability of these waters in irrigation.

The results of the conductivity and SAR analysis show a spatial typology of stations which are characterized by low-risk water, excellent water quality with an absence of strong alkalinization (S1) at very high risk, poor water quality, and a very strong alkalization of waters (Tables 3, 4 and Fig. 9).

Table 3: Irrigation water quality scale based on electrical conductivity (Harivandi 1999).

Conductivity (Ce)	Water classes	Interpretation
Ce < 250µS.cm^{-1}	C_1	Low risk
250µS.cm^{-1} < Ce <[750µS.cm^{-1}]	C_2	Medium risk
750µS.cm^{-1} < Ce <[2250µS.cm^{-1}]	C_3	High risk
2250µS.cm^{-1} < Ce <[5000µS.cm^{-1}]	C_4	Very high risk

Table 4: Irrigation water quality scale in relation to SAR.

SAR	Water classes	Interpretation
0 < SAR <=10	S_1	excellent at low risk of alkalinization
10 < SAR <18	S_2	good with acceptable alkalinization hazards
18 < SAR <26	S_3	medium qualities with a high risk of alkalinization
SAR > 26	S_4	poor qualities with high alkalization risks

Source: (Durand 1982)

The water from stations S3 and S4 cannot be used except for very tolerant crops; otherwise, the water is unusable, because it is very dangerous on poorly drained soils and can present a danger to a certain extent on most crops.

The US Salinity Laboratory (14) scale of analysis results shows that irrigation water from the M'Pourie plain is class C1S1, i.e. irrigation water with low salinity and excellent alkalinity (Fig. 9).

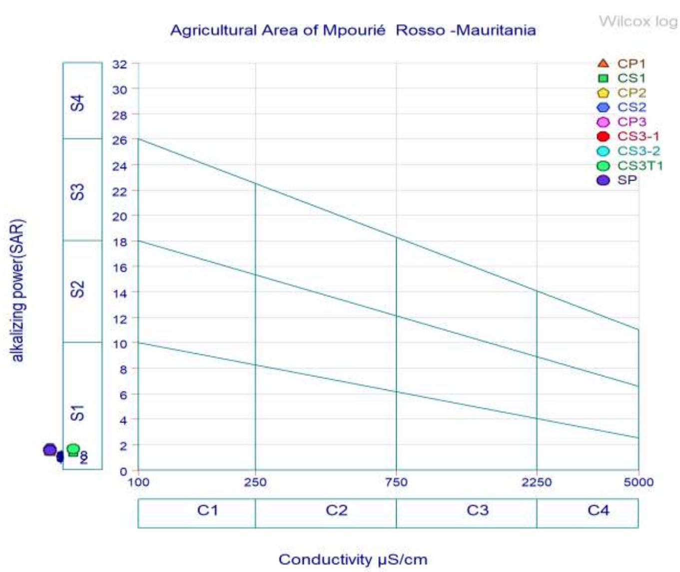

Fig. 9: SAR /Conductivity assessment.

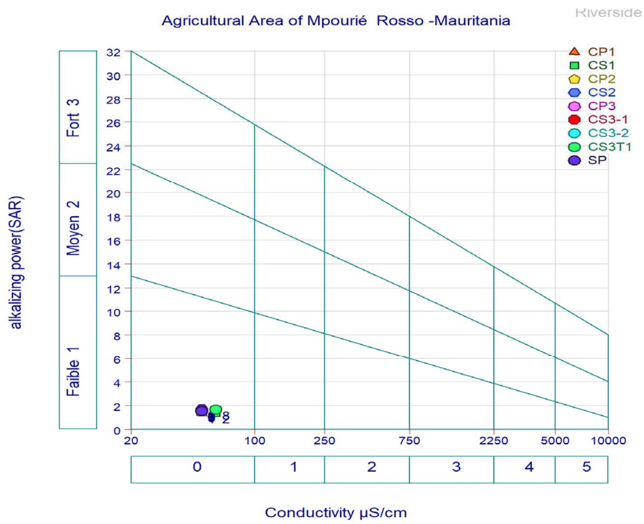

Fig. 10: RIVERSIDE diagram.

Riverside Diagram Classification

Taking into account this classification and after plotting all the water points from the various campaigns on the Richards diagram, according to the SAR/conductivity cross-index, we were able to identify the presence of the following class: C1S1 (Fig. 9 and Fig.10)

CONCLUSION

Our study aimed to evaluate the quality of Senegal River water utilized for agriculture in the M'Pourie plain located in Rosso. This is a crucial matter considering the increasing need for surface water due to the expanding agricultural practices. The water quality findings from the M'Pourie plain in Rosso deliver significant insights, particularly with regard to pH levels that fall within the acceptable range. The low mineralization confirms that the water is ideal for irrigation, and the salinity effect indicates the absence of permeability issues linked to overall salinity. The excessive use of fertilizers and other products in agricultural areas has resulted in high nitrite and ammonium levels in the irrigation water of the M'Pourie plain. However, the nitrate values meet the toxicity standards and do not pose any general problems for irrigation.

Moreover, the levels of sodium, sulfate, bicarbonate, and chloride are within Moroccan standards. The sodium adsorption ratio and electrical conductivity indicate that the Senegal River water used for irrigation in the M'Pourie plain is categorized as class C1S1, indicating low-salinity, excellent water with a low risk of alkalinization. While the waters of the Senegal River, especially those of the main M'Pourie canal, are generally suitable for irrigation, the concerned authorities must keep a check on them and update them regularly.

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