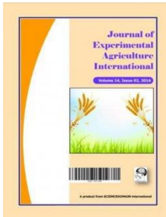

Journal of Experimental Agriculture International

18(3): 1-14, 2017; Article no.JEAI.36480
Previously known as American Journal of Experimental Agriculture
ISSN: 2231-0606

Influence of Prolonged Drought on Groundwater Quality: Irrigated Perimeter of Lower Acaraú – State of Ceará– Northeast of Brazil

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Authors' contributions

This work was carried out in collaboration between all authors. The author LLSC was a master's student and this article is part of his dissertation, this author conducted the study, collected the analyzes in the field and did the statistical analysis of the data, wrote the protocol and wrote the first draft of the manuscript. The authors CFL and FBL were the masters of the first author, they designed the study and monitored and supervised all of this study. The author CMC assisted in literature searches, writing in the manuscript and discussing the data. The authors RRGF and RNAF helped in the search of the literature and in the translation of the same into English language. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2017/36480
Editor(s):
(1) Abdel Razik Ahmed Zidan, Professor, Hydraulics and Water Resources, Mansoura University, Egypt.
Reviewers:
(1) C. R. Ramakrishnaiah, Visvesvaraya Technological University, India.
(2) N. M. Rolli, Bldea's Degree College, India.
Complete Peer review History: http://www.sciencedomain.org/review-history/21602

Received 29th August 2017
Accepted 19th October 2017
Published 27th October 2017

Original Research Article

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ABSTRACT

This study had with objective to evaluate the influence of climatic seasonality and dry season prolonged on parameters of the groundwater quality of irrigated perimeter of lower Acaraú - Ceará, for the years 2010, 2011, 2015 and 2016. Hydrochemical analyzes of the attributes of HCO^{3-}, Ca^{2+}, Cl^{-}, Mg^{2+}, K^{+}, pH, EC, SAR and Na+ in the periods of june (2011; 2015; 2016) and november (2010; 2015; 2016) were performed in six ponds for comparison with previous study. In 2016 it was held on reading the water level of the ponds to identifythe water table variation. The cluster analysis was applied by software SPSS 16.0, where the means of the groups were compared by the T test with 5% significance and presented in boxplot. The Piper Diagram was used in the classification and evaluation of waters. The methodology of the Salinity Laboratory of the United States was used in the evaluation of irrigation water quality with the use of Qualigraf software. The groundwater dynamics indicated that the prolonged drought reduced the water the level of the water table. There was the formation of two groups. Group 1 did not indicatethe reduction of rainfall in the years 2012 to 2016, showing similarity with the attributes of the year 2011 to 2015 and 2016. The elevation of salinity indicator variables in group 2 was obtained due to their location. The classes of irrigation water ranged from C_1S_1 to C_3S_2.

Keywords: Water resources; drought; multivariate analysis; irrigated areas.

1. INTRODUCTION

In the previous period the current climatic changes, the population of the semi-arid region already lived with periods of prolonged drought that affected agricultural activities and life conditions. As a result of several periods of prolonged drought, the experiences of coexistence with this one, serve to analyze the way the population reacts to the situations of scarcity, either by learning and adaptation or even by the increase of socio-environmental conflicts [1].

The perspective of increases in the frequency and duration of dry periods in future climates in the Brazilian Northeast region has generated concern among natural resource managers, farmers and researchers, who try to understand how these changes will affect water resources, food production, income and subsistence. In the period from 2010 to 2015, only 2011 had above-average rainfall, but this was followed by the most severe rainfall deficits in 2012, suggesting a multi-year nature of the current drought, of which the first signs began in 2010 [2].

The irregular rainfall system is characteristic of the semi-arid region of Brazil, with great spatial and temporal variation and a short period of rain (January to April), followed by a long dry period (May to December) [3]. In the state of Ceará, the amount of precipitation is modified by large-scale atmospheric circulation, which is influenced by the El Niño and La Niña phenomena, as well as by the Atlantic Ocean sea surface temperature variation in its north and south tropical portions [4].

It is very important to identify the water quality as well as check their vulnerability to human activity, so that an adequate management of the water resources with respect their use and conservation has be regarded [5]. It is also important to identify the adequacy of the main uses of human consumption and irrigation [6].

To determine the quality of the water, it is necessary to evaluate the variables indicative of changes in climatic seasonality, to identify the multivariate characteristics. Multivariate techniques have been used in the natural sciences to interpret matrices generated by the monitoring of natural processes [7]. The use of this tool has the purpose of identifying the characteristics of the studied objects by the similarities of the processed parameters [8].

However, this study had with objective to evaluate the influence of climatic seasonality and dry season prolonged on parameters of the groundwater quality of irrigated perimeter of lower Acaraú - CE, for the years 2010, 2011, 2015 and 2016.

2. MATERIALS AND METHODS

The study area corresponds to the irrigated perimeter of the lower Acaraú - DIBAU (Fig. 1), located near the coastal region of the northern part of the State of Ceará, near the final stretch of the Acaraú river basin, encompassing the municipalities of Acaraú, Bela Cruz and Marco. The geographical coordinates that delimit are 3º01'00 "to 3º09'00" S and 40º01'00 "to 40º09'00" W. The research was performed in the months of June and November of the years of 2015 and 2016 and compared with study conducted in the years 2010 and 2011 by [9].

The Perimeter covers an irrigable area of 12.407 hectares, where the supply source of the DIBAU is the Acaraúriver, which is perennialized by five different and sequential reservoirs Acaraú-Mirim, Ayres de Souza, Edson Queiroz, Forquilha and Paulo Sarasate [10].

The climatic classification of the studied area is of type Aw', tropical rainy, with summer-autumn rains [11], presenting average annual temperature 28.1°C, minimum of 22.8 °C and maximum of 34.7°C, with average annual precipitation of 960 mm and potential evaporation of approximately 1600 mm per year.

The average precipitation occurred in the meteorological station of the Marco for the years 2010 (371 mm year^{-1}), 2011 (1262.1 mm year^{-1}), 2015 (740.8 mm year^{-1}) and 2016 (757.3 mm year^{-1}) were concentrated in the months of January to June, characteristic of the region, with precipitations not exceeding 350 mm month^{-1} for the period studied. In 2011 there was a higher record and better distribution of rainfall in the rainy season, when compared to other years (Fig. 2, [12]).

The geology of the area is represented by Tertiary formation, with sediments of the Barreiras Group, being this one, characterized by deposits of little consolidation, generally originating deep and well drained soils. The relief area covering the DIBAU is flat to gently corrugated, having a strong longitudinal slope [13].

Six ponds were selected set by a previous study, along with the perimeter map (Fig. 1), field trips, to enable the achievement of collection. The established points were enumerated and georeferenced (Table 1) by GPS type GARMIN MAP 76CSX in UTM and converted to SIRGAS 2000 geographic coordinates.

These points the C32, C34 and C35 are exclusively used for human consumption, as the C08, C36 and C37 are used only for irrigation. Overall, 37 samples were analyzed. The C32 and C35 ponds are in the vicinity of the irrigated perimeter and are indirectly influenced by irrigation management, the others are inserted in the irrigated plots and are directly influenced by the type of irrigation management.

The C35 is located in a community near the Santa Rosa dam, which perpetuates the Acaraú river, and also the DIBAU pumping area; Already the C36 is located near the main channel of the Perimeter; The lot of the C37 is located near the margins of the highway CE 178; The C32 is located in a community, being this one belonging to the coastal basin and is outside the useful area of the Perimeter; The C08 lot is in the vicinity of a community, which is also close to an area of native vegetation.

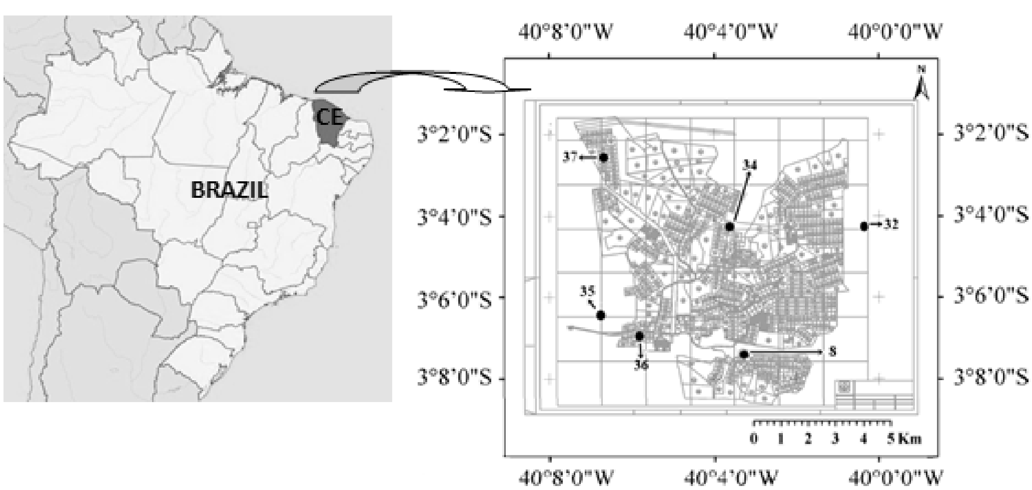

Fig. 1. Localization of irrigated perimeter of lower Acaraú-CE

To identify the influence of prolonged drought (2012 to 2016) in ponds and possible changes during periods of dry and wet, the attributes were analyzed bicarbonate (HCO_3^-), calcium (Ca^{2+}), chloride (Cl^-), electric conductivity (EC), magnesium (Mg^{2+}), potassium (K^+), hydrogenion potential (pH), sodium adsorption ratio (SAR) and sodium (Na^+), compared to the previous study performed at the points in the periods of November 2010 and June 2011 by Luna [9] with the collections held in June 2015, November 2015, June 2016 and November 2016. The analyzes were determined by the methodology of Richards [14], which 324 data were collected (6 ponds, 6 collection periods and 9 attributes analyzed).

In order to investigate the prolonged drought effect on the variation of the blade of the ground water was held reading blade level in ponds in 2016, evaluated together with the data of rainfall that occurred in the study area. For the years 2010 and 2011, data from previous work by Luna [9] were available on the same points. For this, a water level meter was used, where the length of the cable was measured at ground level until reaching the surface of the water. The water blade was made by the difference between the depth of the pond and the measured water level.

The data were grouped using cluster analysis (agglomerative hierarchical method), by the software Statistical Package for Social Science for Windows - SPSS 16.0. In order to eliminate the scalar effect and the different units, the standardization of the variables was performed in standard scores (score Z). The algorithm of agglomeration employment was that of Ward. The measure of similarity was the square Euclidean distance. The optimal number of clusters was defined by the agglomeration coefficient, where sudden increases in the value of the coefficient represent a fusion of different elements in the dendrogram, which are represented by the highest values of the distance [15].

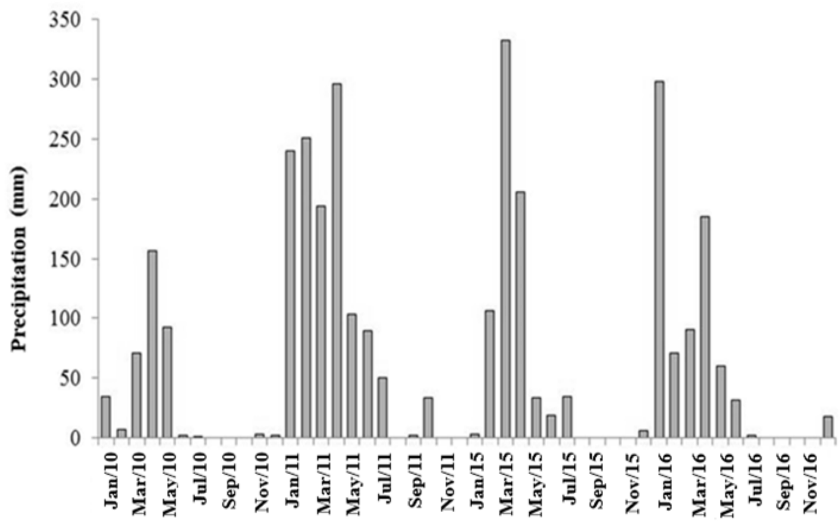

Fig. 2. Precipitation occurred at the meteorological station of the municipality of Marco in the years 2010, 2011, 2015 and 2016

Table 1. Points established for the collection of samples and their geographic coordinates and depth (SIRGAS 2000)

Points	Identification	Latitude (South)	Longitude (West)	Depth (m)
C08	T4/2/A2	-3.1225	-40.0545	11.45 m
C32	Fernando stream	-3.0679	-40.0069	20.15 m
C34	C17/3	-3.0715	-40.0629	13.40 m
C35	Santa rosa	-3.1073	-40.1232	12.65 m
C36	C7/A1	-3.1149	-40.0963	17.00 m
C37	C70/1	-3.0413	-40.1107	21.13 m

The groups formed by the cluster had their means compared by the T test at the level of P< 0.05 of probability, through the program SPSS 16.0. In order to present a descriptive analysis of the behavior of the ions, the central tendency (median), the percentile and the variability of the values (amplitude, extremes, discrepant), the boxplot technique was used, contributing to the evaluation of spatio-temporal effects in Quality of water.

The classification of water for irrigation was performed by Qualigraf software taking into account the parameters of EC and SAR. The methodology of the United States Salinity Laboratory was used to identify if the samples presented a risk of salinization and / or sodification of soils [14].

3. RESULTS AND DISCUSSION

3.1 Groundwater Dynamics

Overall, the pools are influenced by precipitation (Fig. 3), featuring a similar behavior, with higher blade water at the end of the rainy season and lower blade at the end of the dry period, indicating the influence of seasonality in the dynamic level the pools, and the great contribution of precipitation in water storage in soil and consequent rise in the water table level, a fact confirmed byDilon and Goldstein [16] and Andrade et al. [17].

A significant increase in water depth was observed in ponds in 2011, according to the study given by Luna [9], as a result of rain in that year (1262.1 mm yr^{-1}) compared to the other years, since it is the natural mechanism of recharge. Based on Fig. 3, there is that in the years 2010 and 2011, the ponds located in no irrigated areas (C32 and C35) were more sensitive to precipitation, with a greater increase in the blade of the water table than in points they are in irrigated areas (C08, C34, C36 and C37). The latter are directly influenced by irrigation management, showing a different behavior, indicating that there was a water recharge caused by the occurrence of irrigation at the points inserted in this area, a fact also observed by Luna [9], in the same places of the present study.

The performance of Irrigated Perimeters, associated to irregular rainfall regime and high evapotranspiration rates in semi-arid regions, can cause changes in the soil and water salts contents, consequently causing increases in the concentration of toxic ions and elevation of the groundwater level [18].

In 2010 there was a lower precipitation than in 2016, however, the water blade was lower than in 2010. This fact is due to the lower occurrence of precipitation in the five years prior to 2016 (cumulative of 3,200.6 mm) than in the five prior to 2010 (accumulated 4,536.5 mm). It was also observed that there was a sudden decrease in the water table in C32, C34, C35, C36 and C7 from the year 2011 to 2016, mainly in the ponds located in the irrigated area, due to the increase in the use of these as sources in the Irrigation, due to the suspension of water supply from the Santa Rosa dam for use of irrigated lots. This confirms that drought has influenced the increase in the use of these sources, mainly to supply the water needs of crops and to obtain productivity in the period of low water availability.

In the year 2016, the points belonging to the non-irrigated area presented low variation. The C32 showed a lower decrease than in the other points in 2016 (0.38 m). This point is outside the perimeter, in addition to being the farthest point of the area, its water recharge occurs more slowly. The C35 receives significant influence on the water table recharge by the Acaraúriver, because it is near the Santa Rosa dam and presents dynamics similar to that of the Acaraú River.

3.2 Evaluation of the Effects of Prolonged Drought on Water Quality

In the cluster analysis, the first largest variation, by the agglomeration coefficient, occurred between the coefficients 208, 238-350,000, in the passage from the formation of 2 to 1 group, identifying that the number of suitable groupings are 2 groups (Table 2).

Fromdendrogram (Fig. 4) determining the cut-off point isat the time the clustering coefficient, the rescaled distance, showsthe greatest variation (12.596 to 25.000) determined by interpolating the coefficients, where there is a greater distance in similarity measure subsequent to the formation of clusters.

Group 1 consists of the waters of C08 (November / 2010 and June / 2011), C32, C34, C35, C36, C37; Already group 2 is composed of waters was formed only by point C08 (November 2015 and 2016 and June 2015 and 2016). Despite the high precipitations occurred in 2011

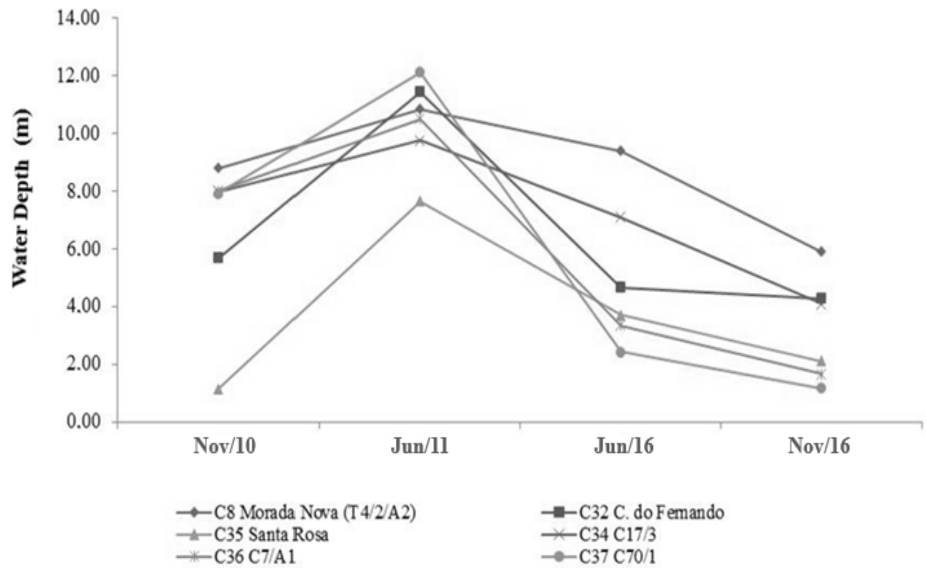

Fig. 3. Variation of groundwater in perimeter irrigated Low Acaraú-CE

(1,262.1 mm) there was no difference between this and other years, this is due to the decrease of the concentration of attributes by the higher precipitations in the years prior to 2010, in addition, C08 presents higher level of the groundwater than the other points, due to being located in the lower area of the perimeter, indicating the possibility of the presence of salts carried from other areas, thus, the decrease of this level in the years of 2015 and 2016 may have caused the worsening of the increase of salts in this reservoir.

The determination of the clusters was due to the hydrochemical composition of the attributes, not having a greater influence of the temporal variability (dry and rainy season), being these data similar to those given by Salgado[3] that studying the similarity of the hydrochemical variables in the salty basin identified that the climatic seasonality was not determinant in the formation of the groups. Water quality studies of Apodi Lagoon were carried out by Brasília: Ministry of Health in 2011Spatial and temporal variability was found [19].

The average values of the minimum and maximum attributes studied the composition of the water perimeter irrigated low Acaraú are described in Table 3.

For sodium (Fig. 5A) the groups differed statistically at the 5% level of significance. Group 1 had the highest mean value (11.53 mmolc L^{-1}).

For human consumption, the average of group 2 is above the drinking water standards of Ordinance MS Nº 2914 of 12/12/2011 [20] which is 200 mg L^{-1} (8.7 mmolc L^{-1}), exceeding 32.53% of the Recommending, while group 1 is within the limits of potability. High levels of sodium in water are often related to cardiovascular diseases [21].

In studies conducted by Luna [9], in the same points of the present study, in 2010 and 2011, it was observed that there were no values above the recommended limit of potability. In this period, the decrease of sodium is associated with the higher precipitations that occurred in previous years, it points out that precipitation was 68% above the normal average of the region.

For irrigation, the mean value of group 2 has a severe degree of restriction, limiting its use, while the mean value of group 1 presents no restriction, according to studies given by Cajazeiras [22]. With the increase of the sodium parameter, there is a worsening of water quality, its use in irrigation without proper management can cause serious problems to the soil by increasing the concentration of salts and exchangeable sodium, which reduces its fertility and, inresearch work by Ayersand and Westcot [23]. In addition, it is important to note that in the long term, it may promote a higher concentration of salts in the groundwater or lead to degradation and even contribute to the desertification of the affected area.

Table 2. Variation of the agglomeration coefficient for the cluster analysis for comparison purposes

Groupings	Coefficients	Difference between coefficients	Rescaled Distance
8	48.068	7.566	1.000
7	55.634	8.502	1.680
6	64.136	13.096	2.445
5	77.232	15.930	3.622
4	93.162	35.355	5.054
3	128.517	48.526	8.233
2	177.043	137.957	12.596
1	315.000	-	25.000

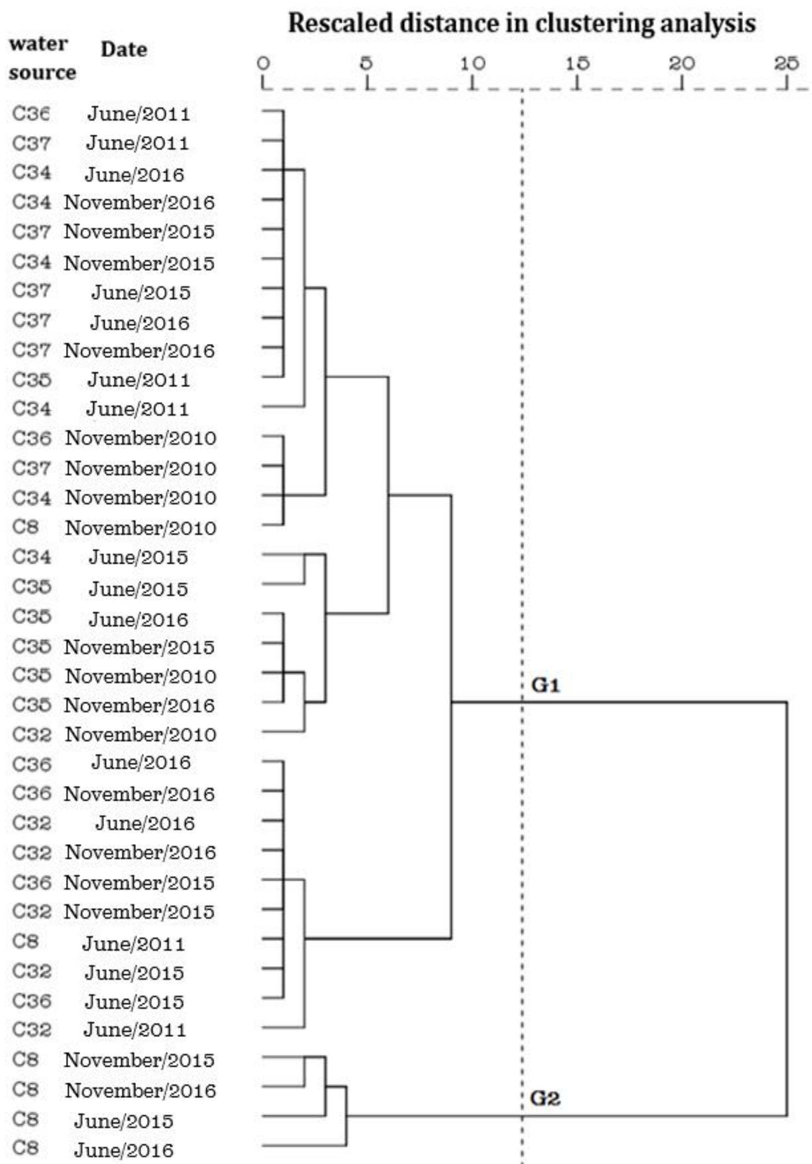

Fig. 4. Similarity of the ionic concentrations of the waters of the ponds in the perimeter irrigated Low Acaraú-Ceará, for comparison purpose

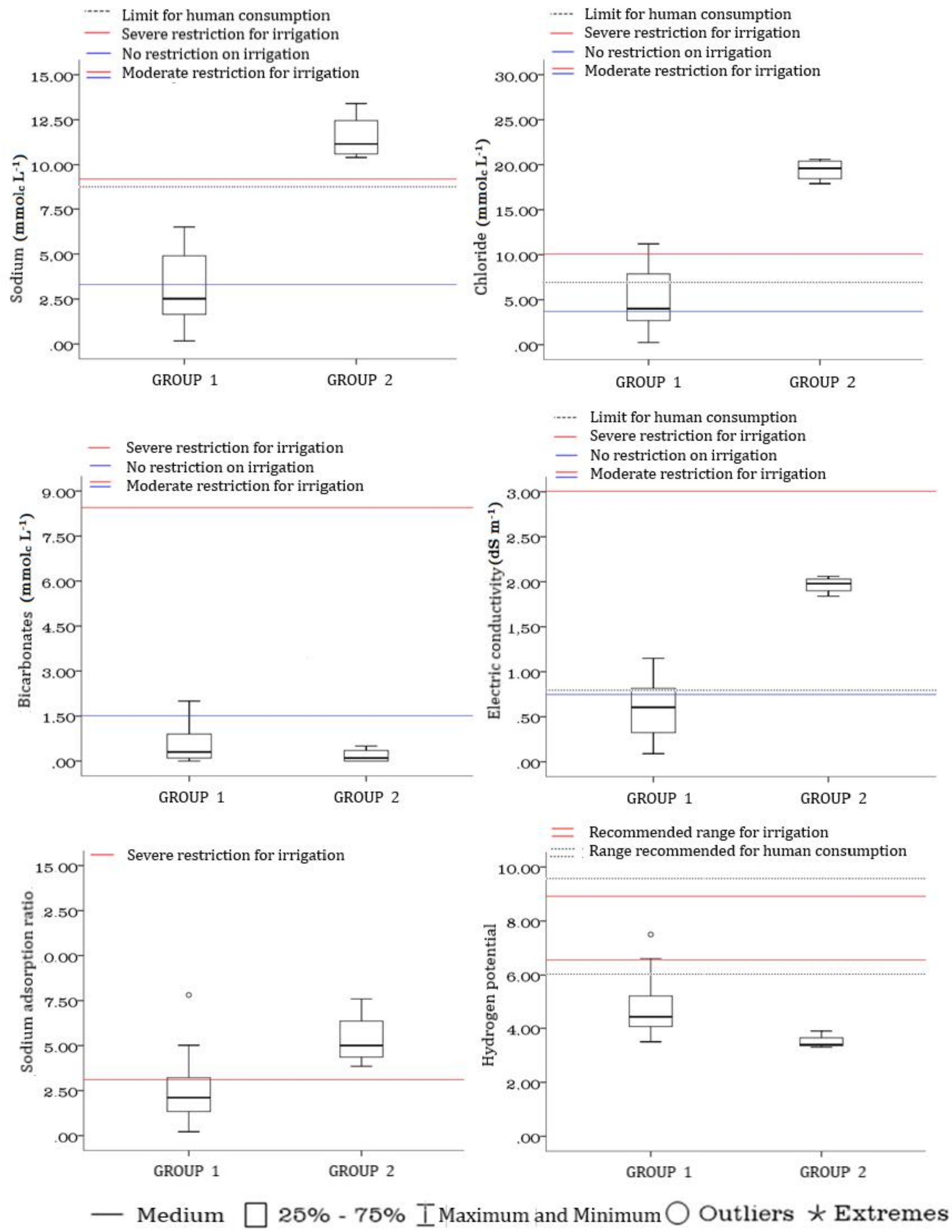

Fig. 5. Statistical analysis of descriptive attributes (A - sodium, B - chloride, C - bicarbonates, D - electric conductivity, E - sodium absorption ratio, F - hydrogen potential) studied for waters of the ponds supplies at the perimeter irrigated low Acaraú – Ceará

According to evaluation given by Ribeiro et al. [24] the quality of the surface waters of the irrigated district of Tabuleiros in Piauíhadlow values, they did not exceed 1 mmolc L^{-1}, presenting no risk of sodicity. In the studies carried out byFigueredoJúnior et al. [25] in the quality of groundwater and surface water in the municipality of Aurora was found in two pools with moderate restriction for use in irrigation.

Table 3. Mean, minimum and maximum values the attributes of the groups formed by DIBAU ponds, for comparison purposes

Attributes	Group 1			Group 2		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
$Ca^{2+}(mmol_cL^{-1})$	0.51b	0.04	1.50	1.38 a	0.70	2.20
$Mg^{2+}(mmol_cL^{-1})$	1.55b	0.58	3.60	5.63 a	4.60	6.60
$K^{+}(mmol_cL^{-1})$	0.37 b	0.04	1.27	1.13a	0.50	2.60
$Na^{+}(mmol_cL^{-1})$	3.09 b	0.17	6.50	11.53a	10.40	13.40
$Cl^{-}(mmol_cL^{-1})$	4.86b	0.25	11.20	19.42a	17.90	20.60
$HCO_3^{-}(mmol_cL^{-1})$	0.53a	0.00	2.00	0.18a	0.00	0.50
EC(dS m^{-1})	0.59b	0.09	1.15	1.97 a	1.84	2.06
SAR	2.45 b	0.21	7.81	5.36 a	3.85	7.59
pH	4.81 b	3.50	7.50	3.50 a	3.30	3.90

Means not followed by the same letter between the groups within each variable differ by the T test at the 5% probability level

The behavior of the chlorides parameter resembled that of the sodium parameter. For chloride, the means of the groups allowed to identify statistical differences. The mean value of group 1 (Fig. 5B) is within the range of potability, established by Ordinance MS Nº 2914 of 12/12/2011 (<250 mg L^{-1}) [19]. Group 2 presented very high values (689.41 mg L^{-1}), exceeding the upper limits of potability. [9] observed that during the dry period, P9, which is equivalent to C08 of this study, was one of the points that presented the highest average value, but not exceeding the limits established for potability standards.

For the chloride parameter for irrigation, group 2 presented severe restriction (> 10 mmolc L^{-1}), differently from group 1 that presented moderate. In group 2 (C08), probably the increase of these levels was motivated by its location, which had the effect aggravated by the drought of the last years, which gave greater concentration of this parameter by the decrease of the groundwater in the years of 2015 and 2016. When in the irrigation water, high levels of chloride are absorbed by the roots of the plants and transported to the leaves, accumulating and causing burning at the edges of the leaves, especially in conditions of high evapotranspiration [26].

Also the presence of the chloride ion may have been due to the proximity that the study area has of the sea coast, being this influenced by the marine waters and aerosols that increase the concentrations of this attribute in groundwater. Maia et al. [27] also observed the increase of this ion due to the influence of the sea coast, which with the occurrence of precipitations and winds, allow the entry into the soil and consequent contamination of the groundwater.

The elevation of sodium and chloride salts contents in the perimeter irrigated low Acaraú are mainly due to edaphic and hydrogeological factors, since the region is in the lower part of the lower third of the Acaraú basin, where there is predominance of sandy alluvial soils and crystalline and sandstone derivatives. The area is bathed by waters from the drainage of the crystalline soils of the upper part of the basin [15].

The bicarbonate content (Fig. 5C), it was observed that there was no statistically significant difference between groups. Group 1 presented higher value (0.53 mmolc L^{-1}) than group 2. According [9] the values found for bicarbonates were considered low. For irrigation, no mean value was restricted (<1.5 mmol L^{-1}), but it was observed that group 1 presented the highest variation of the data, with moderate restriction for samples collected.

For the electrical conductivity parameter (Fig. 5D), group 2 presented the highest mean value (1.97 dS m^{-1}), differing statistically significantly, which corresponds to the high values of cations (Na^{+}, Ca^{2+}, Mg^{2+} , K^{+}), indicating a higher concentration of salts in group 2 than in the other groups, confirming the results obtained by Luna [9] and Gomes and Cavalcante [28]. Group 2 presented lower EC values, not exceeding 0.60 dS m^{-1}.

According to Resolution 357/05 of CONAMA [29], the average of the values obtained for group 1 can be considered as fresh water due to salinity equal to or less than 0.78 dS m^{-1}; For the water samples collected from group 2, by the same resolution, can be considered brackish, because they presented values of salinity higher than 0.78 dS m^{-1} and less than 4.68 dS m^{-1}. This group had lower variability, when compared to group 1, represented by the opening of boxplot boxes.

For the mean of group 2, for the degree of restriction according to [22], the restriction is moderate, it is recommended to pay more attention to the type of crop used and the irrigation management so that it can be reached adequate yield potential. As for the mean of group 1, it was observed that there is no restriction for use in irrigation. High levels of salt content in irrigation water can both impair crop development and cause obstruction of irrigation systems [30]. Irrigation with low quality water can bring undesirable elements to the soil in excessive amounts, affecting its fertility [31].

In studies carried out by Nishanthiny et al. [32] in the quality of irrigation water from reservoirs in the Acaraú river basin, electrical conductivity values lower than the restriction limit for irrigation use were found.

EC elevation in groundwater is also related to rainfall through the aerosols that are transported by the rains and accumulated in the soils and fractures. In the crystalline areas there is no continuous network of the regional flow, so large differences in salinity from one fracture to another are often observed [33].

SAR attribute (Fig. 5E) the groups differed statistically significantly. Group 1 presented a mean value of 2.50 (Fig. 5E), being within the recommended for use in irrigation (<3,00), however with maximum values of 7.50. Group 2 presented mean above that recommended for irrigation.

BRAZIL. ANA - NATIONAL AGENCY OF WATERS [34] compared, water quality for irrigation in three water systems in the semi-arid region they found a risk of medium to high sodicity in well water. Souza et al. [35] investigated the water quality of the Orós reservoir in the semi-arid region,they observed that irrigated water presented no risk of sodicity, since SAR values were lower than the restriction limit for irrigation.

The evaluation of SAR is important to determine the suitability of water for irrigation, since excessive levels of sodium over calcium and magnesium reduce soil permeability and, consequently, inhibit the supply of water necessary for crops [36].

pH (Fig. 5F) the groups differed statistically, and the waters of the groups presented pH values tending to the acidity condition. None of the groups averages presented values within the potability standards for human consumption, established by decree MS Nº 2914 of 12/12/2011 [19], which should be between 6.0 and 9.5, the other groups are out of the standards of potability.

In general, the waters had low pH values. This acidity characteristic can result in corrosion to certain materials [27]. This is an abiotic attribute, important in aquatic ecosystems and difficult to interpret by the amount of factors that can affect it [37].

According to Esteves [38] the pH tends to be higher when bicarbonates are present in the water; This fact can be observed in the averages of the groups, where there is a higher presence of bicarbonates, the pH values are higher and where there is less presence, the pH values are lower, by the directly proportional ratio of bicarbonate content and values of pH.

Maia et al. [27] reported that the pH is essentially a function of dissolved carbon dioxide (CO_2) and the soils available organic acids that increase the acidity of the groundwater, contributing to low pH. [28] and [9] to the same study also found pH corresponding to acidic condition.

It was observed that at point C35 the pH value approached the neutrality, probably due to the location, since it is near the Acaraúriver, which is perennialized by the Santa Rosa dam. In the Santa Rosa dam a pH variation of 6.9 to 7.5 was observed for the years 2015 and 2016 in the months of june and july (data not shown), already in the C35 for that same period of study was found a variation of pH from 6.3 to 7.5, noting the similarity with the waters of the Acaraú River. For irrigation, none of the mean values of the groups presented pH values between the usual range, established by the limits of the values between 6.5 and 8.4.

The classification of water for irrigation by the methodology of the U.S Salinity Laboratory is described in Fig. 6, taking into account only the points in use of irrigation (C08, C36 and C37).

Based on Fig. 6, it can be observed that the water samples collected at the points studied provided values that allow us to identify that

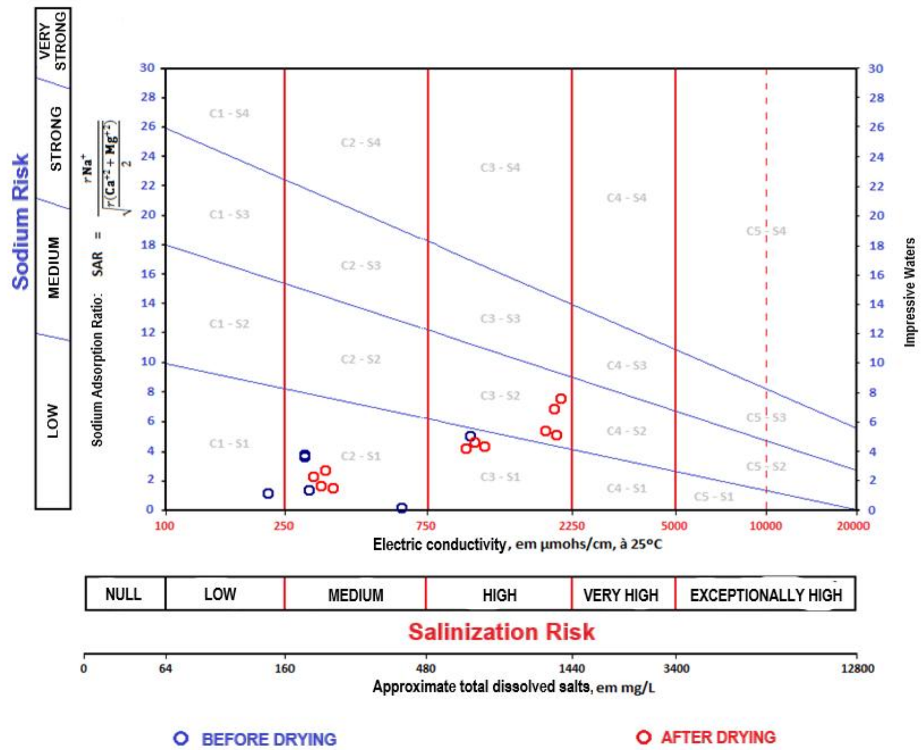

Fig. 6. Classification of groundwater of the groups used for irrigation of DIBAU, for comparison purposes

the samples vary between C_1S_1 classes in which it is equivalent to 5.6% of the total samples (C36 November/2010), C_2S_1 representing 44.4% (C08 November/2010, C36 June/2011; P37), C_3S_1 equivalent to 27.8% (C08 June 2011, C36 June/2015 and 2016 and November / 2015 and 2016) and C_3S_2 equivalent To 22.2% (C08 June and November 2015 and 2016). Thus, as already mentioned in the paper, the greatest influence of the dry season on irrigation waters was only for C08, which is located in the depressive area of the study area DIBAU.

Hermes and Silva [39] studied the reservoir water quality in DIBAU, in periods prior to the present study, observed that in the rainy season the classes ranged from C_1S_1 to C_2S_1 and in the dry period it was C_2S_1. Lobato et al. [40] analyzed the groundwater quality in the municipality of Frecheirinhawater was classified as C_3S_1.

White et al. [41] warn about the need for careful control of water used in irrigation, especially when the electrical conductivity and sodium adsorption ratio are underestimated as C_1S_1 may exhibit similar behavior to C_1S_5 waters, as the rate of infiltration, due to the dispersion of colloids.

4. CONCLUSION

The dynamic groundwater indicated that prolonged drought periods reduces the level of water blade in ponds as a result of decreased recharge, and increased use of these water sources for irrigation; There was the formation of two groups, where for the samples Group 1 did not have any influence by the reduction of precipitation in the years 2012 to 2016 showing similarity to the attributes in 2011 to that observed after five years of drought (2015 and 2016); The indicator salinity variables (EC, Cl^- and Na^+) increased in group 2 as a function of the proximity of depressional areas in the irrigated receive influence of recharge water and salts from elevated areas, a situation aggravated by prolonged drought periods which low the level groundwater and increase concentrations of the ions in the period of the study;In the classification of the irrigation waters the classes C_1S_1 to C_3S_2 were identified, meaning low to high risk of salinity and medium to high risk of sodicity.

ACKNOWLEDGEMENTS

The authors thank the Postgraduate Program in Agricultural Engineering of the Federal University of Ceará - UFC for all the support during the development of the research. The first author thanks the Coordination of Improvement of Higher Education Personnel - CAPES/Brazil for the grant of the Master's Degree.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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