Vol. 13(44), pp. 2471-2476, 1 November, 2018
DOI: 10.5897/AJAR2018.13429
Article Number: 4B33B6759097
ISSN: 1991-637X
Copyright ©2018
Author(s) retain the copyright of this article
http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Groundwater quality monitoring for agriculture irrigated in Catolé Do Rocha, Paraíba State, Brazil

Evandro Franklin Mesquita[1*], Lourival Ferreira Cavalcante[2], Francisco Thiago Coelho Bezerra[2], Jackson Mesquita Alves[1], José Thyago Aires Souza[2], Caio Silva Sousa[1], Antonio Gustavo Luna Souto[2] and Danila Araújo de Lima [2]

[1]Universidade Estadual da Paraíba, Center for Agrarian and Human Sciences (CCHA), Zip Code: 58.884 – 000, Catolé do Rocha, Paraíba, Brazil.
[2]Universidade Federal da Paraíba, Center for Agricultural Sciences, Zip Code: 58.397-000, Areia, Paraíba. Brazil.

Received 1 August, 2018; Accepted 19 September, 2018

The electrical conductivity and of cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) and anions (Cl^{-}, CO_3^{2-}, HCO_3^{-} and SO_4^{2}) contents of the water an Amazon well, from State University of Paraíba, Catolé do Rocha city, Paraíba State, Brazil, located in the semi-arid region of the Brazilian High Sertão were evaluated monthly from January to December of year 2017. Despite the increase in electrical conductivity from 0.89 to 1.16 mS cm^{-1} and sodium adsorption ratio (SAR) from 4.43 to 10.45 $(mmol\ L^{-1})^{1/2}$ did not change the water quality to agriculture. With mean risk to saline (C2) and low risk to exercise sodicity at soil (S1), toxicity and nutritional imbalance to plants, the concentration of dissolved salts increased from 0.57 to 0.74 g L^{-1} between rainy and arid periods. This situation expresses a high increase of almost 30% in the total dissolved salts during the evaluated period and shows the need for systematic monitoring. Simulating the irrigation with a 400 mm blade of this water with 1.16 dS m^{-1}, in 120 days, can add to soil 2,970 kg ha^{-1} of salts, of which 1,892; 633; 258 and 143 kg ha^{-1} are of the sodium, calcium, potassium and magnesium species, respectively.

Key words: Water quality, ionic components of water, salinity of water in well.

INTRODUCTION

Agriculture, in Brazil and worldwide, is the activity that consumes the most water in comparison to the consumption of human, herds and industrial (Oliveira et al., 2013; Holanda et al., 2016). This peculiarity, in part, is due to insufficient and irregular rainfall, high temperature air and soil, low humidity, high evaporation rates and evapotranspiration. Beyond the quantitative aspects (regular rainfall and volume of water available), specifically in agriculture, the world also needs chemical quality water that allows the use in the irrigation without causing high edaphic degradation and high cultures production losses (Cavalcante et al., 2012; Ganiyu et al. 2018). In addition to these inconveniences, the surface and groundwater salt content in semi-arid areas, which is generally above the limits tolerated by plants to human food and animals importance, results in a serious

*Corresponding author. E-mail: elmesquita4@pq.cnpq.br.

Author(s) agree that this article remain permanently open access under the terms of the Creative Commons Attribution License 4.0 International License

irrigated agriculture obstacle (Andrade Júnior et al., 2006; Ammari et al., 2013; Koff et al., 2017). When considering the limitations of water resources, in quantity and quality, and the growing demand for food in the world for nearly fifty years, have awakened as an alternative the use of restrictive water due to the excess of salts for irrigation of plants of economic importance (Costa; 1982; Silva Júnior et al., 1999; Rhoades et al., 2000; Ben-Asher et al., 2006; Holanda et al., 2016; Vieira et al., 2016; Murad et al., 2018). However, even assuming this need not all high waters salt concentration, such as sea water or equivalent concentration, should be used for irrigation. This assertion is based on Ayers and Westcot (1999), Cavalcante et al. (2012) and Holland et al. (2016), when they affirm that plants with food and commercial importance are, in great majority, low or medium tolerance to the water salinity.

The use of water with restrictions due to excess salts in irrigated agriculture, irrespective of the source (surface or underground source), requires the monitoring of the electrical conductivity, cation and dissolved concentrations (Medeiros et al., 2003; Barroso et al., 2011; Jang et al., 2012; Oliveira et al., 2013; Lira et al., 2015; Chu et al., 2016; Rassol et al., 2017; Ganiyu et al., 2018). This monitoring, if possible, should be at various times of the year, considering one or more sources of property, municipality or watershed, making possible a specific panorama and the elaboration of strategies of use of this water resource.

The salinity studies the total concentration of salt mixture effects, or saline complex, dissolved in the irrigation water - CS (g L^{-1}); the value can be estimated by the product between the water electrical conductivity-ECw (dS m^{-1}) and the 0.64 multiplication factor waters with up to 5 dS m^{-1} or 0.80 for salinity water higher than 5 dS m^{-1} (Rhoades et al., 2000). The total salt concentration can also be obtained analytically by the calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+) and sodium (Na^+) quantification in equivalence with chloride (Cl^-), bicarbonate (HCO_3^-), carbonate (CO_3^-) and sulfate (SO_4^{2-}) (Richards, 1954). Toxicity refers to the specific effects of some ions such as sodium, chloride, magnesium, boron and the ratio of sodium to total cations dissolved in water. Sodium is evaluated by the sodium adsorption ratio - SAR (Ayers and Westcot, 1999), by the value of residual sodium carbonate (RSC) which is the difference between the sum of carbonate plus bicarbonate plus calcium plus magnesium RSC = (CO_3^{2-} +HCO_3^-) - (Ca^{2+} + Mg^{2+}) (Richards, 1954; Almeida, 2010; Maskooni et al., 2017). The aim of this study was to monitor monthly the electrical conductivity and the cationic and anionic contents in amazon well water.

MATERIALS AND METHODS

The work was carried out in experimental area of the Center for Human and Agrarian Sciences, State University of Paraíba, Campus - IV, municipally Catolé do Rocha, State of Paraíba, Brazil. Water samples were collected monthly, from January to December 2017, from an Amazon well (6° 21' 11"S, 37° 43' 21" W and 244 m above sea level) with a diameter of 4 m, depth of 11 m and an annual mean daily flow of 2.2 m^3 h^{-1}. The region climate is BSwh', according to Köppen classification (Alvares et al., 2013), defined as hot semi-arid. The municipality rainfall is less than 800 mm and are irregularly distributed in the rainy season, with more than 65% precipitated from February to April month; the annual averages temperature and relative humidity are, respectively, 27°C and below 50%. The soil of the area, according to the criteria of the Brazilian Soil Classification System (Embrapa, 2013) was classified as Eutrophic Entisol. The physical and chemical properties (fertility and salinity) in a sample of 0-0.2 m layer of this soil were analyzed (Embrapa, 2017) with their values given in Table 1.

The electrical conductivity of the water was determined by direct reading in conductivity. Ca^{2+} + Mg^{2+} was analyzed by complexometry with disodium EDTA, using Eriochrome-Black as an indicator. Ca^{2+} determined by complexiometry in the presence of carbonic acid indicator calcone. Na^+ and K^+ were determined flame spectrometer. For CO_3^{2-} and HCO_3^- the titration was with H_2SO_4 using the respective indicators, phenolphthalein and methyl orange. After determination of carbonate and bicarbonate was added K_2CrO_4 and titrated with $AgNO_3$ for determination of Cl^-. SO_4^{2-} was determined in photocolorimeter after the addition of HCl and $BaCl_2.2H_2O$ (Richards, 1954). The average of monthly data of electrical conductivity and ion concentration were related to each other by a regression test. For each ionic component was calculated the minimum, average and maximum (Silva Júnior et al., 1999). The average of the mean electrical conductivity and ion concentration of each component was used to simulate the irrigation full blade 400 mm, according to the following equation (Richards, 1954; Rhoades et al., 2000):

$$Sad = (Ecw \times 0.64 \times Iwd) / 1,000;$$

were: Sad = total salts added by water (kg ha^{-1}); Ecw = Electrical conductivity water (dS m^{-1}); Iwd = Irrigation water depth (mm), 1 mm = 10 m^3 ha^{-1} = 10,000 L ha^{-1}, thus 400 mm is equivalent to 4,000,000 L ha^{-1}. The quantification of each sais added was calculated from the total volume applied and their respective participation in the water.

RESULTS AND DISCUSSION

The electrical conductivity in the period from January to December/2017 increased from 0.89 to 1.16 dS m^{-1} resulting in a saline increase of 30.3%; this value is considered high and already uses moderate restraint (Ayers and Westcot, 1999; Medeiros et al., 2003; Almeida, 2010, Cavalcante et al., 2012, Holanda et al., 2016) the great importance economic cultivated plants. The relation between the electrical conductivity and the total dissolved salts (TDS) in water (Figure 1) was 64%. This level expresses high dispersion, but the increasing factor between both is consistent with Richards (1954) and shows the dependence between the electrical conductivity and the total dissolved salts, with 80% correlation contents salts water dissolved, due to the increase in electrical conductivity of the water. In this way, it is verified that although the electrical conductivity correlates with the content of dissolved salts, it does not faithfully represent the concentration of salts but by its

Table 1. Physical and chemical (fertility and salinity) attributes of the Eutrophic Entisol where the Amazonas well installed.

Physical attributes		Chemical attributes			
		Fertility		Salinity	
Sand (g kg^{-1})	661	pH (in H_2O)	6.7	pH (in extract)	7.7
Silt (g kg^{-1})	213	P (mg kg^{-1})	25	Ecw (dS m^{-1})	1.30
Clay (g kg^{-1})	126	Ca^{2+} ($cmol_c$ kg^{-1})	4.41	Ca^{2+} ($mmol_c$ L^{-1})	3.99
Pd (kg dm^{-3})	1.52	Mg^{2+} ($cmol_c$ kg^{-1})	1.31	Mg^{2+} ($mmol_c$ L^{-1})	1.26
Sd (kg dm^{-3})	2.75	Na^{+} ($cmol_c$ kg^{-1})	0.22	Na^{+} ($mmol_c$ L^{-1})	5.84
Porosity (m^3 m^{-3})	0.45	K^{+} ($cmol_c$ kg^{-1})	0.76	K^{+} ($mmol_c$ L^{-1})	2.17
		H^{+}+Al^{3+} ($cmol_c$ kg^{-1})	0.00	Cl^{-} ($mmol_c$ L^{-1})	10.00
		SB ($cmol_c$ kg^{-1})	6.70	CO_3^{2-} ($mmol_c$ L^{-1})	0.00
		CEC($cmol_c$ kg^{-1})	6.70	HCO_3^{-} ($mmol_c$ L^{-1})	2.98
		ESP (%)	3.28	SO_4^{2-} ($mmol_c$ L^{-1})	0.20
				SAR (mmol L^{-1})$^{1/2}$	3.61

Pd - particle density; Sd - soil density; SB - sum of bases; CEC - cation exchange capacity; ESP - exchangeable sodium percentage; Ecw - water electrical conductivity; SAR - sodium adsorption ratio.

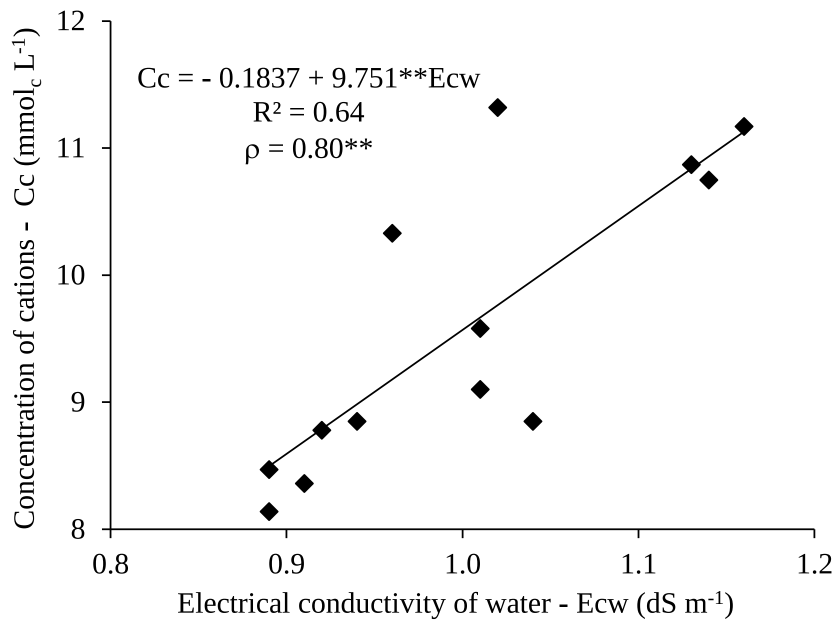

Figure 1. Concentration of cations as a function of the electrical conductivity of water in Amazon well.

value the total solubilized in water (Richards, 1954; Rhoades et al., 2000; Holanda et al., 2016) and in the soil is estimated (Cavalcante et al., 2012; Ribeiro et al., 2016).

In Figure 2, it shows the mean, average and maximum values of cations, anions and electrical conductivity throughout the year 2017. The order of the mean cation contents was 7.06 (Na^{+}) > 1.36 (Ca^{2+}) > 0.83 (Mg^{2+}) > 0.32 (K^{+}) $mmol_c$ L^{-1}, for the anions of 7.45 (Cl^{-}) > 1.87 (HCO_3^{-}) > 0.42 (SO_4^{2-}) > 0.15 (CO_3^{2-}) $mmol_c$ L^{-1} and, the electrical conductivity of water amplitude was 0.89 to 1.16 dS m^{-1} with 1.01 dS m^{-1} mean (Figure 2). These values fluctuate with the mineralogical nature, with the intensity of the transformation of the source material and with the solubility of the primary components of the soils, especially the sodium, calcium and magnesium contents (Ribeiro et al., 2016).

Among the cations the predominance is sodium and anions the chloride, with concentrations in general similar, but with chloride (7.45 $mmol_c$ L^{-1}) supremacy in relation to sodium (7.06 $mmol_c$ L^{-1}) (Figure 3), which is why most scientific investigations refer to both species as

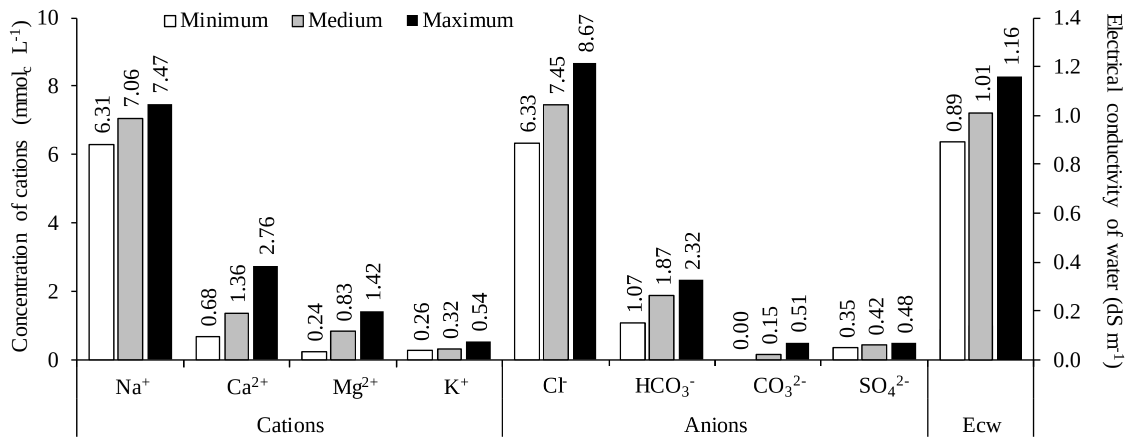

Figure 2. Minimum, mean and maximum values of cations, anions and electrical conductivity of water in Amazon well.

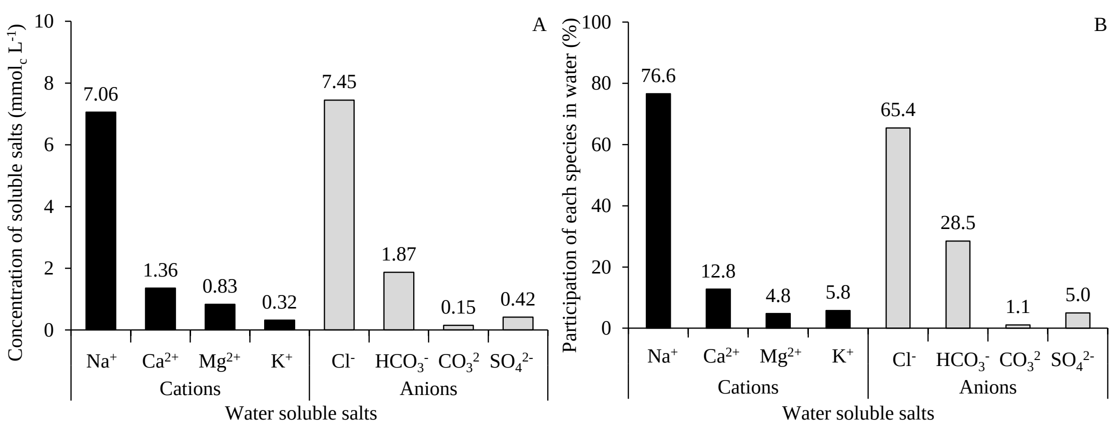

Figure 3. Concentration (A) and percentage participation (B) of soluble ionic species in water of the one Amazon well.

expressed the literature on salinity. This superiority, compared to the other components of each species, is not only due to the aggressive action of Na^+ in the soils physical attributes depletion, but also in the structure loss and pore space reduction to the root growth, nutritional and plant toxicity (Richards, 954; Ayers and Westcot, 1999; Almeida, 2010).

Despite the higher molar concentration of chloride compared to sodium, the percentage share of sodium exceeds chloride within valence, obeying the order 76.6 (Na^+) > 12.8 (Ca^{2+}) > 5.8 (K^+) > 4.8 (Mg^{2+}) for cations and 65.4 (Cl^-) > 28.5 (HCO_3^-) > 5.0 (SO_4^{2-}) > 1.1 (CO_3^{2-}) for ions (Figure 3B). These orders differ from those obtained for the concentrations (Figure 2) because they are calculated based on the concentration in mg L^{-1} and vary according to the equivalent each species weight (Cavalcante et al., 2012). This situation resembles the sequences presented by Silva Júnior et al. (1999), Costa (1982), Medeiros et al. (2003), Andrade Júnior et al. (2006), Leal et al. (2009), Barroso et al. (2011), Oliveira et al. (2013) and Holanda et al. (2016), respectively for crystalline Brazilian Northeast waters in the Paraíba, Piauí, Rio Grande do Norte and Ceará, States all of which are inserted in Brazil semi-arid region.

The reported situation resembles the sequences recorded by Jang et al. (2012) in Taiwan, Hassanli and Ebrahimian (2016) in Karaj, Maskooni et al. (2017) in Iran, Rassol et al. (2016) in Pakistan, Koffi et al. (2017) in Ghana, Gill and Terry (2016) in Australia, Ganiyu et al. (2018) in Nigeria, among many others. The results also show that composition terms and salt content the semi-arid world present situation, even considering the differences in soil source materials, is very similar between the West and the East lands. Waters with electrical conductivity of up to 1.16 dS m^{-1}, even if they had moderate restrictions on plants and soil, if the world had enough water for irrigation to meet the world food and livestock requirements, it would suggest less employment saline waters in agriculture. This statement seems consistent since soil irrigation with depth water 400 mm (1.16 dS m^{-1}) during drought 120 days in the Catolé do Rocha municipality, Paraíba State, Brazil, with Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}, concentrations respectively, 2.59, 1.29, 6.75 and 0.54 $mmol_c$ L^{-1}, would add to the soil a total of 2,970 kg ha^{-1} which salts, 1,892, 633, 258 and 187 kg ha^{-1} are salts of sodium, calcium, potassium and magnesium, respectively.

Conclusions

The Amazon well water electrical conductivity during the 2017 year increased from 0.89 to 1.16 dS m^{-1}. The salts total added to the soil with an irrigation depth of 400 mm was 2,970 kg ha^{-1}, of the 63.7; 21.3; 8.7 and 6.3% corresponded to salts of sodium, calcium, potassium and magnesium. The amplitude of the electrical conductivity and the addition of salts of the soil by a water depth not high, justify the monitoring of the quality of irrigation water in the semiarid region from anywhere in the world.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGMENTS

The authors thank the National Council for Technological Development Scientific (CNPq), the Higher Education Personnel Coordination (CAPES) and the Science Technology in Salinity National Institute (INCTSal), respectively, for the awarding of scientific initiation scholarships in undergraduate, postgraduate Master's degree, PhD and research productivity and financial aid to carry out the project activities.

REFERENCES

Almeida AO (2010). Qualidade da água de irrigação. 1ª ed. Cruz das Almas: Embrapa Mandioca e Fruticultura 227 p.

Alvares CA, Stape JL, Sentelhas PC, Gonçalves JLM, Sparovek, G (2013). Köppen's climate classification map for Brazil. Meteorologische Zeitschrift 22(6):711-728.

Ammari TG, Tahhan R, Abubaker S, Al-Zu'bi Y, Tahboub A, Ta'any R, Abu-Romman S, Al-Manaseer N, Stietiya MH (2013). Soil Salinity Changes in the Jordan Valley Potentially Threaten Sustainable Irrigated Agriculture. Pedosphere 23(3):376-384.

Andrade Júnior AS, Silva EFF, Bastos EA, Melo FB, Leal CM (2006). Uso e qualidade da água subterrânea para irrigação no Semi-Árido piauiense. Revista Brasileira de Engenharia Agrícola e Ambiental 10(4):873-880.

Ayers RS, Westcot DN (1999). A qualidade da água na agricultura. 2ª ed. Campina Grande: UFPB (FAO, Estudos de irrigação e drenagem, 29, revisado) 153 p.

Barroso AF, Gomes EG, Lima AEO, Palácio HAQ, Lima CA (2011). Avaliação da qualidade da água para irrigação na região Centro Sul no Estado do Ceará. Revista Brasileira de Engenharia Agrícola e Ambiental 15(6):588-593.

Ben-Asher J, Tsuyuki I, Sagih M (2006). Irrigation of grapevines with saline water I. Leaf area index, stomatal conductance, transpiration and photosynthesis. Agricultural Water Management 83(1-2):13-21.

Cavalcante LF, Oliveira FA, Gheyi RR, Cavalcante IHL, Santos PD (2012). O maracujazeiro e a salinidade da água. João Pessoa: Sal da Terra, 400 p.

Chu LL, Kang YH, Wan SQ (2016). Effect of different water application intensity and irrigation amount treatments of microirrigation on soil-leaching coastal saline soils of North China. Journal of Integrative Agriculture 15(9):2123-2131.

Costa RG (1982). Caracterização da qualidade de água de irrigação na microrregião homogênea de Catolé do Rocha (MRH -89), Dissertação (Mestrado em Engenharia Agrícola), Universidade Federal da Paraíba. Campina Grande.

Embrapa-Centro Nacional de Pesquisa de Solos (2013). Sistema Brasileiro de Classificação de Solos. 3ª ed. Brasília: Embrapa Solos 353 p.

Ganiyu SA, Badmus BS, Olurin OT, Ojekunle ZO (2018). Evaluation of seasonal variation of water quality using multivariate statistical analysis and irrigation parameter indices in Ajakanga area, Ibadan, Nigeria. Applied Water Science 8(1):8-35.

Gill BC, Terry AD (2016). 'Keeping salt on the farm'- Evaluation of an on-farm salinity management system in the Shepparton irrigation region of South-East Australia. Agricultural Water Management 164(1):291-303.

Hassanli M, Ebrahimian H (2016). Cyclic use of saline and non-saline water to increase water use efficiency and soil sustainability on drip irrigated maize in a semi-arid region. Spanish Journal of Agricultural Research 14(44):1204-1218.

Holanda JS, Amorim JRA, Ferreira Neto M, Holanda AC, Sá FVS (2016). Qualidade da água para irrigação. In: Gheyi HR, Dias NS, Feitosa CF, Gomes Filho E. Manejo da salinidade na agricultura: estudos básicos e aplicados. 2ª ed. Fortaleza: INCTSal. Cap. 4:35-50.

Jang CS, Chen SK, Kuo YM (2012). Establishing an irrigation management plan of sustainable groundwater based on spatial variability of water quality and quantity. Journal of Hydrology 11(1):414-415.

Koffi KV, Obuobie E, Banning A, Wohnlich S (2017). Hydrochemical characteristics of groundwater and surface water for domestic and irrigation purposes in Vea catchment, Northern, Ghana. Environmental Earth Science 76(185):1-19.

Leal CM, Andrade Júnior AS, Sousa WF, Silva EFF, Bastos EA (2009). Qualidade da água subterrânea para fins de irrigação na microrregião de Teresina, Piauí. Irrigation 14(3):276-288.

Lira RM, Santos NA, Silva JS, Barnabé JMC, Barros MS, Soares HR (2015). A utilização de águas de qualidade inferior na agricultura irrigada. Revista GEAMA 1(3):341-362.

Maskooni EK, Kompanizare M, Afzali SF (2017). Chemical assessment of dam water irrigation effects on groundwater qualities in Bigherd plain, Fars Province, Iran. Environmental Earth Science 76(238):1-14.

Medeiros JF, Rodrigo RA, Lisboa RA, Oliveira O, Silva Júnior MJ, Alves LP (2003). Caracterização das águas subterrâneas usadas para irrigação na área produtora de melão da Chapada do Apodi. Revista Brasileira de Engenharia Agrícola e Ambiental 7(3):469-472.

Murad KFI, Hossain A, Fakir OA, Biswas SK, Sarker KK, Rannu RP, Timsina J (2018). Conjunctive use of saline and fresh water increases the productivity of maize in saline coastal region of Bangladesh. Agricultural Water Management 204(2):262-270.

Oliveira HA, Bezerra HN, Araújo JMS, Tavares LAF (2013). Qualidade de águas de poços dos assentamentos da chapada do Apodi - RN para o uso na agricultura. Holos 1(1):64-72.

Rassol A, Xiao T, Farooqi A, Shafeeque M, Liu Y, Kamran MQ, Katsoyiannis IA, Samas E (2017). Quality of tube well water intended for irrigation and human consumption with special emphasis on arsenic contamination at the area of Punjab, Pakistan. Environmental Geochemical Health 39(4):847-863.

Rhoades JD, Kandiah A, Mashali QM (2000). Uso de Águas salinas para produção agricola. Tradução de Gheyi, H. R.; Sousa, J. R.; Queiróz, J. E. Campina Grande: UFPB (Estudos FAO: Irrigação e Drenagem, 48) 117p.
Ribeiro MR, Ribeiro Filho MR, Jacomine PKT (2016). Origem e classificação dos solos afetados por sais. In: Gheyi HR, Dias NS, Feitosa CF, Gomes Filho E. Manejo da salinidade na agricultura: estudos básicos e aplicados. 2ª ed. Fortaleza: INCTSal. Cap. 2:9-16.
Richards LA (1954). Diagnostico y rehabilitación de suelos salinos y sódicos. México: Departamento de Agricultura de los Estados Unidos de América (Manual de Agricultura, 60). 174 p.
Silva Júnior LGA, Gheyi HR, Medeiros JF (1999). Composição química de águas do cristalino do Nordeste brasileiro**.** Revista Brasileira de Engenharia Agrícola e Ambiental 3(1):11-17.
Vieira IGS, Nobre RG, Dias AS, Pinheiro FWA (2016). Cultivation of cherry tomato under irrigation with saline water and nitrogen fertilization. Revista Brasileira de Engenharia Agrícola e Ambiental 20(1):55-61.