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# MAPPING AND CHARACTERIZATION OF GROUNDWATER USED FOR IRRIGATION IN THE VAZANTES DISTRICT REGION, ARACOIABA – CE

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## 1 RESUMO

Objetivou-se georreferenciar a distribuição de poços rasos destinados a irrigação e consumo humano, bem como caracterizar a qualidade da água dessas fontes hídricas no distrito de Vazantes, em Aracoiaba-CE. O trabalho foi realizado no distrito de Vazantes, localizado no município de Aracoiaba, na região do Maciço de Baturité, Ceará. Foram avaliados sete poços do tipo amazonas, também denominados de cacimba, na qual as coletas das amostras de água foram realizadas em recipiente de garrafas plásticas, PETs, de 250 mL devidamente limpas e hermeticamente fechadas e encaminhadas ao laboratório para análise. As amostras foram coletadas no mês de julho de 2022, período referente ao final da estação chuvosa. Os parâmetros avaliados foram: condutividade elétrica da água ($CE_a$), potencial Hidrogeniônico (pH) e sais dissolvidos totais (SDT). A qualidade da água subterrânea nos poços avaliados apresentou inadequações nos parâmetros pH e $CE_a$ quanto aos padrões de potabilidade, na qual o poço P5 apresentou desconformidade quanto á condutividade elétrica, enquanto que o poço P3 apresentou desconformidade para o pH. A grande maioria dos poços avaliados (P1, P2, P4, P6 e P7) apresentaram parâmetros em conformidade com a legislação, podendo ser utilizados pelos proprietários tanto para a irrigação como para as atividades domésticas.

**Palavras-chaves:** qualidade da água, irrigação, sensoriamento remoto.

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## 2 ABSTRACT

The objective was to georeference the distribution of shallow wells used for irrigation and human consumption, as well as to characterize the water quality of these water sources in the district of Vazantes, in Aracoiaba-CE. The work was carried out in the district of Vazantes, located in the municipality of Aracoiaba, in the region of Maciço de Baturité, Ceará. We evaluated seven wells of the Amazonas type, also known as cacimba, in which the water samples were collected in properly cleaned and hermetically sealed 250 mL plastic bottles (PET) and sent to the laboratory for analysis. The samples were collected in the month of July 2022, the period referring to the end of the rainy season. The parameters evaluated were: water electrical conductivity ($EC_w$), hydrogen potential (pH) and total dissolved salt (TDS). The quality of the groundwater in the wells evaluated showed inadequacies in the pH and $EC_w$ parameters with regard to potability standards, in which well P5 presented nonconformity regarding electrical conductivity, while well P3 presented nonconformity for pH. The vast majority of wells evaluated (P1, P2, P4, P6 and P7) presented parameters in compliance with legislation and can be used by owners for both irrigation and domestic activities.

**Keywords:** water quality, irrigation, remote sensing.

## 3 INTRODUÇÃO

Groundwater is water present below the surface of the ground and is used as a public and private supply to meet social needs such as human consumption and industry (Deus; Latuf, 2022; Alexandre *et al*., 2021) and is widely used in agriculture. According to the National Water Agency (ANA, 2023), it is estimated that the availability of groundwater in Brazil is approximately 13,205 $m^3$ $s^{-1}$ and that its distribution throughout the national territory is not uniform, given that the hydrogeological characteristics of aquifers are variable. In the regions of the municipalities related to the backlands of Ceará, the hydrogeological domain of the rocks is a crystalline lithology; in general, the deep wells in this region have salinization problems, with the electrical conductivity of most of these water sources varying between 1.0 and 6.0 dS $m^{-1}$ and with a flow rate of less than 3.0 $m^3$ $h^{-1}$ (Lessa *et al*., 2023).

The main characteristic of the semiarid northeastern region is the annual occurrence of irregular rains, with a greater concentration of these rains occurring in the first half of the year, in addition to high temperatures and low relative humidity, which, associated with the geological nature of the region, directly influence the salinization of waters. underground (Nunes *et al*., 2022), considering that the presence of salts in groundwater is directly related to the capacity for mineral dissolution, the lack of water circulation and the predominant types of rock in the region (Leite; Wendland; Gastmans, 2021), which could compromise the use of this water source for irrigation and/or human consumption.

The groundwater used for irrigation represents an important input for northeastern agribusiness, necessitating adequate monitoring of these water sources to manage them in a rational and efficient way while irrigating crops without causing problems with soil salinization. In this sense, Holanda *et al*. (2016) emphasized that the quality of water intended for irrigation must be evaluated in terms of three main aspects: salinity risk, water infiltration into the soil and the toxicity of specific ions to plants. Therefore, the determination of physicochemical parameters provides support for evaluating the possibility of salt precipitation and salinity induction as a result of irrigation practices (Mantovani; Bernardo; Palaretti, 2012).

A survey was carried out by Lessa *et al*. (2023), evaluating the potential of wells with brackish underground waters for use in different agricultural production systems in the northeastern semiarid region, highlighted the need to seek to diversify production systems as well as adopt strategies aimed at using these waters in biosaline agriculture, such as plant tolerance to salt and water demand. Nunes *et al*. (2022), when evaluating the water quality of underground resources for agricultural purposes in the irrigated perimeter of Morada Nova in Ceará, they highlighted the importance of irrigators replacing the surface irrigation method with localized irrigation, enabling the expansion of the irrigated area in the perimeter.

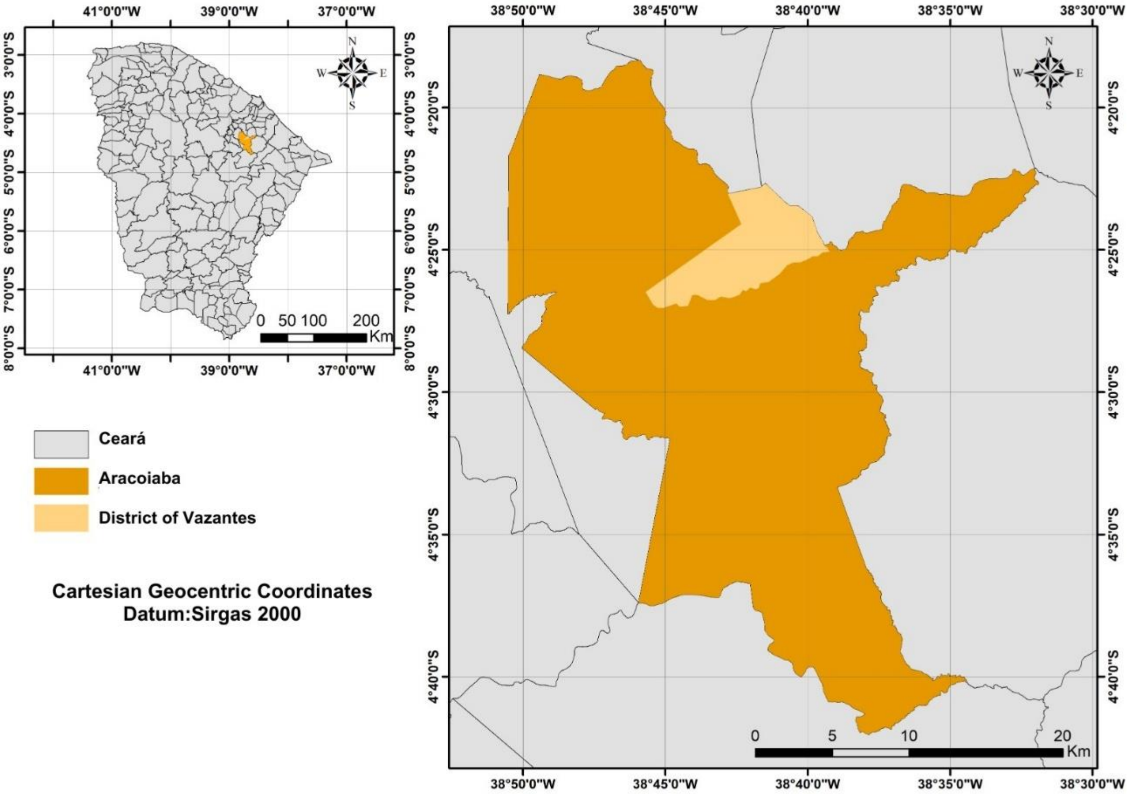
Currently, geographic information systems (GISs) are being widely used to monitor and determine water quality, as well as the spatial distribution of surface and underground water resources. An important tool for monitoring groundwater is the Groundwater Information System (SIAGAS), which is an information system developed by the Geological Survey of Brazil (SIAGAS, 2023). According to Cruz, Resende and Amorim (2010), through GIS, it is possible to manipulate georeferenced attributes quickly through the production of maps, graphs and spreadsheets that enable, for example, the analysis of the spatial behavior of variables indicating the quality of water throughout a given region of interest.

In view of the above, the aim was to georeference the distribution of shallow wells intended for irrigation and human consumption, as well as characterize the quality of water from these water sources in the district of Vazantes, in Aracoiaba-CE.

## 4 MATERIALS AND METHODS

The present work was carried out in the district of Vazantes, which is located in the municipality of Aracoiaba (Figure 1) and is located under the geographic coordinates 4° 25′ 09″S, 38° 42′ 14″W in the Massif de Baturité region at 89 km from the capital Fortaleza – CE, with an altitude of 102 m. The municipality has a hot subhumid tropical climate, with predominant rains in the summer and autumn seasons and droughts in the winter months (Köppen, 1923). The area has an average annual rainfall of 947 mm, which is concentrated between January and May, with an average temperature between 26°C and 30°C (IPECE, 2022).

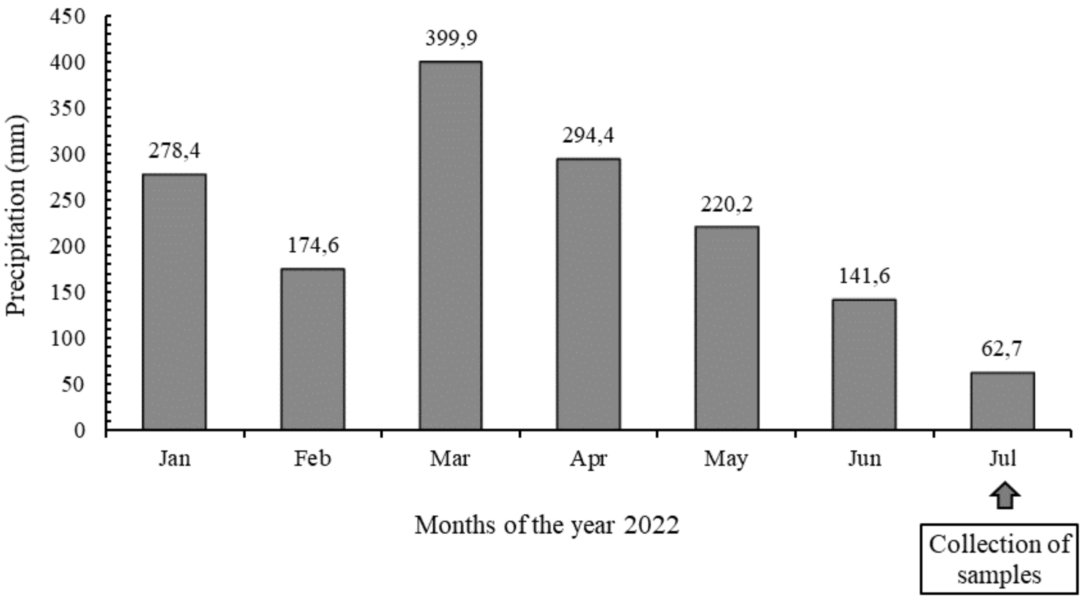
**Figure 1.** Location map of the Vazantes district in the municipality of Aracoiaba-CE.




**Source:** Authors (2023).

Figure 2 shows the precipitation values between January and July for the period 2022 (FUNCEME, 2022).

**Figure 2.** Precipitation values for the period from January to July 2022.




**Source:** Cearense Foundation of Meteorology and Water Resources (2022).

Field visits were carried out with the aim of collecting information and quantifying the distribution of wells in the Vazantes district. Next, the geographic coordinates of the wells were determined through georeferencing with the aid of the GPS (Global Positioning System) model Garmim 76 scx. Using Google Earth Pro software, an image of the study area was obtained and georeferenced in the QGIS 3.32 program to create a spatial distribution map of the wells.

Water samples from seven wells of the Amazon type, also called cacimbas, were evaluated; the water samples were collected in containers made of plastic bottles (PETs) (250 mL), duly cleaned and hermetically closed and subsequently sent to the Bromatology Laboratory, which is located on the Campus das Auroras from the University of International Integration of Afro-Brazilian Lusofonia (UNILAB), for laboratory analysis. The water samples were collected in July 2022, the period corresponding to the end of the rainy season, as shown in Figure 2.

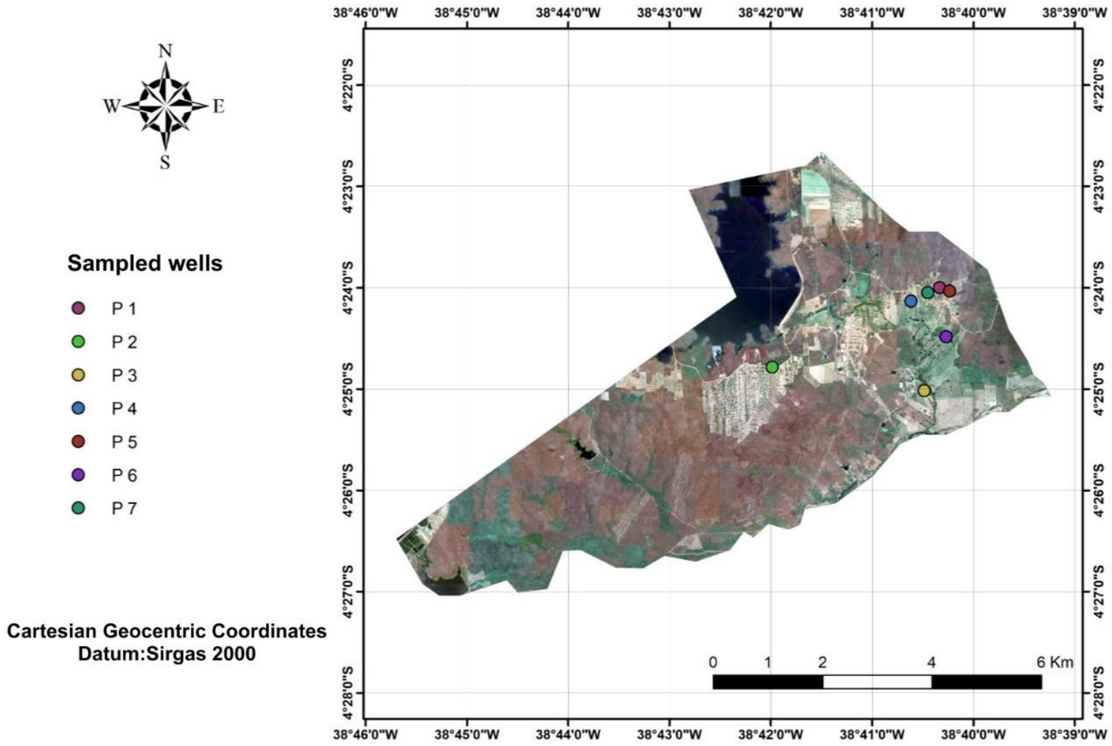
The parameters evaluated were water electrical conductivity ($EC_w$), hydrogen potential (pH) and total dissolved salt (TDS) content. The electrical conductivity was measured using an AZ bench multiparameter device (model 86505), and the hydrogenation potential was determined by an MS TECNOPON pH meter (model mPA210). Total dissolved salt concentrations were calculated based on the electrical conductivity of the water using QualiGraf *software from the* Fundação Cearense de Meteorologia e Recursos Hídricos (FUNCEME, 2014).

After carrying out the analyses, the water characteristics were compared between the wells, and the water quality was compared according to the potability standards of CONAMA Resolution No. 357 of March 17, 2005, for $EC_w$ and pH (BRASIL, 2005) and the Ministry of Health Ordinance No. 2,914/2011 for STD (BRASIL, 2011).

## 5 RESULTS AND DISCUSSION

The spatial distribution of the wells in which the water samples for evaluation were located and collected is shown in Figure 3. The wells are distributed among surrounding communities that make up the district of Vazantes and are located on private properties dug by the owners themselves.

**Figure 3.** Location of the wells where water samples were collected in the Vazantes district.




**Source:** Authors (2023)

Agricultural and livestock activity is quite widespread in the region. In times of drought, where water scarcity limits these activities, groundwater becomes an alternative use, with the use of this water source in the region mainly for irrigation, human consumption, animal husbandry and domestic activities. Groundwater directly contributes to the expansion of irrigated agriculture in different regions of the world (Lima, 2022). In Pakistan, 73% of irrigated areas originate from underground sources through tubular wells, which guarantees economic and food security in the region (Qureshi, 2020; Sarwar *et al*., 2021).

A survey was carried out by Azlaoui *et al*. (2021) evaluated the quality of groundwater in the semiarid region of Algeria intended for irrigation and human consumption. The researchers emphasized the importance of monitoring and mapping the geographic distribution and quality of groundwater, which provides the generation of information that can assist in decision-making related to the adoption of policies for the use of these water resources, aiming at better management of these water sources, even for the implementation of irrigation projects.

The physicochemical parameters of the groundwater samples analyzed in this study are shown in Table 1. For the $EC_w$ parameter, 6 samples presented values within the range permitted by legislation (0.340 dS m $^{-1}$) for human consumption, varying between 0.064 dS m $^{-1}$ (P6) and 0.250 dS m $^{-1}$ (P4). The highest level of water salinity was observed in well P5, with an $EC_w$ 0.704 dS m $^{-1}$, which was above what was permitted by legislation (Table 1). Considering that EC is strongly related to the presence of ions and particles electrically charged by dissolved solids, it is believed that the low values of electrical conductivity observed in most wells are attributed to the high rates of rainfall in the region during the rainy season, which contributed to the greater accumulation of groundwater, resulting in a reduction in the salt content of these wells.

**Table 1.** Physicochemical parameters of groundwater in the Vazantes district.

| **Samples** | Parameters | | |
|---|---|---|---|
| | **$EC_w$ (dS m $^{-1}$)** | **pH from water** | **TDS (mg L $^{-1}$)** |
| P1 | 0.149 | 7.1 | 96.85 |
| P2 | 0.128 | 6.8 | 83.20 |
| P3 | 0.157 | 5.8 | 102.05 |
| P4 | 0.250 | 7.7 | 162.50 |
| P5 | 0.704 | 7.3 | 457.60 |
| P6 | 0.064 | 6.5 | 41.60 |
| P7 | 0.073 | 7.4 | 47.45 |
| MVA | 0.340 | 6-9 | 1000 |

Q: Well; MVA: Maximum value allowed; $EC_w$: Electrical conductivity of water; pH: Hydrogenionic potential; TDS: Total dissolved salts.
**Source:** Authors (2023)

Evaluating the quality of water from wells in rural areas in the municipality of Viçosa in Ceará, Magalhães *et al*. (2019) also reported low values of water electrical conductivity, which was also justified by the influence of precipitation during the evaluation period. It is important to highlight that the electrical conductivity of water is the most commonly used parameter for expressing the concentration of dissolved salts in water and is widely used for assessing the quality and classification of water intended for irrigation (Holanda *et al*., *2016*).

The hydrogen potential (pH) is determined by the concentration of hydrogen ions and is used to indicate the degree of acidity or alkalinity of a solution. Most groundwater has a pH between 5.5 and 8.5 (CETESB, 2018). The pH values of the samples from wells P1, P2, P4, P5, P6 and P7 (Table 1) were within the range permitted by legislation for supply, in accordance with the potability standards of CONAMA resolution no. 357 of March 17, 2005, with pH values ranging from 6.5 to 7.7. António *et al*. (2022), evaluating the quality of water from underground sources in the community of Piroás in the municipality of Redenção, CE, also observed pH values similar to those obtained in this work.

Only well P3 presented a pH value (5.8) below that permitted by legislation, making it unsuitable for human consumption. For irrigation, this parameter is highly important; therefore, the detection of an abnormal pH value should be considered a warning that it is necessary to carry out a detailed assessment of the water, as the application of very acidic water can increase the acidity concentration. soil and can cause damage to plants (Almeida, 2010). One factor that may have a direct influence on the pH is the dissolution of rocks present in the crystalline basement in which the wells are located (Silva; Araújo; Souza, 2007).

Total dissolved salts (TDS) are inorganic salts and materials dissolved in water, where the amount of salt is strongly influenced by the geological conditions in which the water sources are located and the amount of rainfall (Braga *et al*., 2021). According to current ordinance nº 2,914/11 (Brasil, 2011), regarding the classification of TDS, all the water samples from the wells were classified as fresh water (TDS < 500 Mg/L) and were within the maximum potability limit. established by an ordinance

(1000 Mg L $^{-1}$); however, the highest value for total dissolved salts was obtained in the water sample from well P5, with a value of 457.60 Mg L $^{-1}$, which was directly proportional to the electrical conductivity of the water, indicating a close relationship between these two physicochemical parameters ($EC_w$ and TDS). Furthermore, it is worth highlighting that salt concentrations in groundwater tend to decrease during the rainy season when the volume of water is significantly greater.

Research was carried out by Alexandre *et al*. (2021) studied the community of Barreiros in Aratuba, CE, by evaluating the quality of water from wells intended for irrigation; the researchers found that the TDS values were similar to those in the present work. Similarly, Mendonça *et al*. (2019), evaluating the quality of groundwater intended for human consumption in the Recôncavo region of Bahia, also verified values for TDS in accordance with legislation.

By comparing the physicochemical parameters of the water samples from the wells analyzed with the reference results for use in irrigation based on FAO bulletin 29 by Ayers and Westcot (1985), expressed in Table 2, a restriction for use was observed regarding the pH only for well P3, which was outside the normal range of use, in which a slightly acidic pH was obtained (5.8).

**Table 2.** Restrictions on water use for irrigation.

| Parameter | Reference value for use in irrigation | Classification |
|---|---|---|
| pH (Hydrogen potential) | 6.5 – 8.4 | Normal range of use |
| $EC_w$ (Electrical conductivity) | <0.700 dS m $^{-1}$<br>0.700 – 3.0 dS m $^{-1}$<br>>3.0 dS m $^{-1}$ | No degree of use restrictions<br>Slight to moderate degree of use restriction<br>Severe degree of restriction of use |
| TDS (Total Dissolved Salts) | <450 Mg L $^{-1}$<br>450 – 2000 Mg L $^{-1}$<br>> 2000 Mg L $^{-1}$ | No degree of use restrictions<br>Slight to moderate degree of use restriction<br>Severe degree of restriction of use |

**Source:** Ayers and Westcot, (1985).

pH is an extremely important parameter in water dynamics because it helps in the precipitation of toxic chemical elements such as heavy metals; therefore, the detection of an abnormal pH value must be considered a warning that a detailed assessment is necessary. Water containing toxic ions can even negatively affect soil fertility and can also damage the root system of plants (Santos *et al*., 2021; Almeida, 2010).

In relation to electrical conductivity, wells P1, P2, P3, P4, P6 and P7 did not present any degree of restriction of use, with a variation from 0.064 to 0.250 dS m $^{-1}$, and can be used for irrigation of most crops in almost all types of soil. Only well P5 presented a moderate degree of use restriction (0.704 dS m $^{-1}$), presenting restrictions for some plants, mainly glycophyte crops that are sensitive to salinity, requiring slightly more caution in irrigation management. However, for Ayers and Westcot (1985), a deviation of 10% to 20% above or below reference values is of little importance, as other factors can affect crop yields. However, it is worth highlighting that some strategies can be adopted to manage irrigation with water containing saline water, such as mixing water of different salinities, cyclically using water, and using saline water in the stages in which the crop shows greater tolerance, in addition to the use of organic fertilizers (Lacerda *et al*., 2016).

Regarding the total dissolved salt concentration in the groundwater of the Vazantes district, similar to the electrical conductivity, the results indicated that wells P1, P2, P3, P4, P6 and P7 did not restrict the use of water for irrigation (<450 Mg $L^{-1}$), which ranged from 41.60 to 162.50 Mg $L^{-1}$ of TDS. On the other hand, only well P5 presented a slight to moderate degree of use restriction, with a TDS value of 457.60 Mg/L. This parameter is also widely evaluated for irrigation purposes and corresponds to the total weight of mineral constituents present in the water; this parameter is substantially composed of sodium, magnesium, chloride, calcium, carbonate and bicarbonate ions (Alexandre *et al*., *2021*). Thus, the use of water with a high content of dissolved salts for irrigation in localized systems, without an adequate management strategy, may cause clogging of emitters, harm plants and cause a decrease in water availability in the soil (Bernardo *et al.*, 2019).

## 6 CONCLUSIONS

The use of geoprocessing techniques, based on tools from Geographic Information Systems (GIS), allowed the spatial distribution of shallow wells in the Vazantes district to be determined.

The quality of the groundwater in the evaluated wells showed inadequate pH and EC parameters in terms of potability standards; for example, the P5 well presented nonconformity in terms of electrical conductivity, while the P3 well presented nonconformity for pH. It is necessary to carry out assessments of other physical-chemical parameters related to water quality, seeking other means of use.

The vast majority of wells evaluated (P1, P2, P4, P6 and P7) presented parameters in compliance with legislation and can be used by owners for both irrigation and domestic activities.

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