ISSN 2359-1919 (Online)
SCIENTIFIC ARTICLE

Water quality in irrigated area for production of robusta coffee (*Coffea conephora*) in the Amazon

Qualidade da água em área irrigada para produção do café robusta (*Coffea conephora)* na Amazônia

Andressa dos Santos Cruz[1], Nara Luisa Reis de Andrade[2],
Adjalma Campos de França Neto[1], Jeferson Alberto de Lima[2]

[1]Universidade Federal de Rondônia, Rolim de Moura, RO, Brasil. E-mails: andressasantos752@gmail.com; adjalma@unir.br
[2]Universidade Federal de Rondônia, Ji- Paraná, RO, Brasil. E-mails: naraluisar@unir.br, jeferson.lima@unir.br

How to cite: Cruz, A. S., Andrade, N. L. R., França Neto, A. C., & Lima, J. A. (2024). Water quality in irrigated area for production of robusta coffee (*Coffea conephora*) in the Amazon. *Revista de Gestão de Água da América Latina*, *21*, e18. https://doi.org/10.21168/rega.v21e18

ABSTRACT: The present work attempts to characterize Robusta coffee producing properties located in the São Miguel do Guaporé– RO river basin and analyze water quality. Collections were carried out on 20 properties and the following parameters were evaluated: Calcium, Electrical Conductivity; Total Hardness; Total Phosphorus; Magnesium; pH; Sodium, Sodium Adsorption Ratio, salinity and sodicity. The pH ranged from 5.2 to 6.5 and 55% of the samples presented results within the limit established by CONAMA 357/2005, and around 70% of these samples presented phosphorus content outside the recommended levels. The water classification regarding salinity and sodicity was C1S3, where C1 means that it does not present any risk of salinity and S3 indicates a severe problem when there is infiltration into the soil due to the sodicity of the water. The results obtained may add technical knowledge on the São Miguel do Guaporé river basin, assisting in sustainable management of soil and water.

Keywords: Water for Irrigation; Salinity; Sodicity; Irrigated coffee farming; Electrical conductivity.

RESUMO: O presente trabalho intenta caracterizar propriedades produtoras do café robusta localizadas na bacia hidrográfica do Rio São Miguel do Guaporé – RO, e analisar a qualidade da água. Foram realizadas coletas em 20 propriedades e avaliados os parâmetros: Cálcio, Condutividade Elétrica; Dureza Total; Fósforo Total; Magnésio; pH; Sódio, Razão de Adsorção de Sódio, salinidade e sodicidade. O pH variou de 5,2 a 6,5 e 55% das amostras apresentou resultado dentro do limite estabelecido pela CONAMA 357/2005, e cerca de 70% dessas amostras apresentou teor de fósforo fora do preconizado. A classificação das águas quanto à salinidade e sodicidade foi C1S3, onde C1 significa que não apresenta nenhum risco de salinidade e S3, indica problema severo quando à infiltração no solo pela sodicidade da água. Os resultados obtidos poderão agregar conhecimento técnico sobre a bacia do rio São Miguel do Guaporé, auxiliando na gestão sustentável do solo e das águas.

Palavras chaves: Água para Irrigação; Salinidade; Sodicidade; Cafeicultura irrigada; Condutividade elétrica.

1. INTRODUCTION

The increase in population, the high degree of deforestation, the intensification of agriculture and livestock farming with unsustainable bases, the deterioration of forests in urban centers, the excessive exploitation of aquifers, among other factors, are qualitatively and quantitatively affecting the available natural resources (Rodrigues, 2021).

Currently, around 40% of all food production comes from irrigated agriculture. A total of 8,2 million hectares in Brazil are equipped for irrigation, and of this total, around 35.5% are fertigations with reused water; for the rest, water from springs is used. Of these 8,2 million hectares, the private sector occupies 96.2% (Agência Nacional de Águas e Saneamento Básico, 2021). The use of water for irrigation corresponds to 49.8% of the water collected for the total demand in Brazil (Agência Nacional de Águas e Saneamento Básico, 2021). The challenge of irrigated agriculture is the promotion of quality irrigation, in this scenario, irrigated agriculture will have the great opportunity to contribute to environmental, water and food security, being able to contribute to reducing the impacts on

Received: May 20, 2024. Revised: August 07, 2024. Accepted: August 16, 2024.

production arising from climate change, guaranteeing food in quantity, quality and affordable costs for people (Paolinelli et al., 2021).

Among the crops that require irrigation, coffee growing can be highlighted. In Rondônia, coffee production has gained prominence in the central region, and approximately 77% of crops have less than 5 ha, becoming, this way, an activity that is part of family farming, therefore having great social importance (Marcolan et al., 2009).

Knowing the quality of the water resource used to irrigate crops contributes to ensuring the nutritional status of both the plant and the soil. However, many times, the real quality of water is different from the quality of water that the crop needs, which may have a close relationship with the conditions of use/occupation of the soil in the river basins, since the vegetation cover of the soil favors an improvement in its physical quality, improved aggregation and increased resistance to water erosion, contributing to increasing its agricultural potential (Silva et al., 2007). Therefore, considering that coffee production is a consolidated culture in the region under study, evaluating the physical and chemical parameters of water in irrigated areas arouses interest in making it possible to understand the quality of the water where this culture occurs, observing, in addition, possible impacts arising from the irrigation process.

Regarding the quality of water for irrigation, it basically refers to three main factors that need to be evaluated, which are Sodicity, Salinity and Toxicity (Almeida, 2010), and, for the establishment of water quality standards, the legal basis is the CONAMA Resolution 357 of March 17, 2005 (Brasil, 2005). Based on the above, the present work aims to identify and characterize the Robusta coffee producing properties located in the São Miguel do Guaporé river basin, in the state of Rondônia, and verify the water quality of the properties that use irrigated coffee farming.

2. MATERIAL AND METHODS

2.1. Location and characterization of the study area

The present study was carried out in the São Miguel do Guaporé River Basin, in a plot located in the municipality of São Miguel do Guaporé - RO (Figure 1).

The São Miguel river basin encompasses five municipalities: Alvorada D'Oeste, Nova Brasilândia do Oeste, São Miguel do Guaporé, Seringueiras and São Francisco do Guaporé, the vast majority (around 93%) being within the last three. It has an area of 9,240.23 km² and a perimeter of 571.73 km, and a vast drainage network: the main river, São Miguel, is 308.06 km long, and all water bodies combined contribute to an extensive network of 5,114.95 km (Amazônia, 2018).

The area chosen for study covers rural coffee-producing properties, which have technical support from Technical and Management Assistance - ATEG, a program offered by the National Rural Learning Service - SENAR that aims to combine technological adaptation and management consultancy. These properties receive monthly and individual visits, carried out by SENAR-RO's technical staff, with a focus on increasing production efficiency.

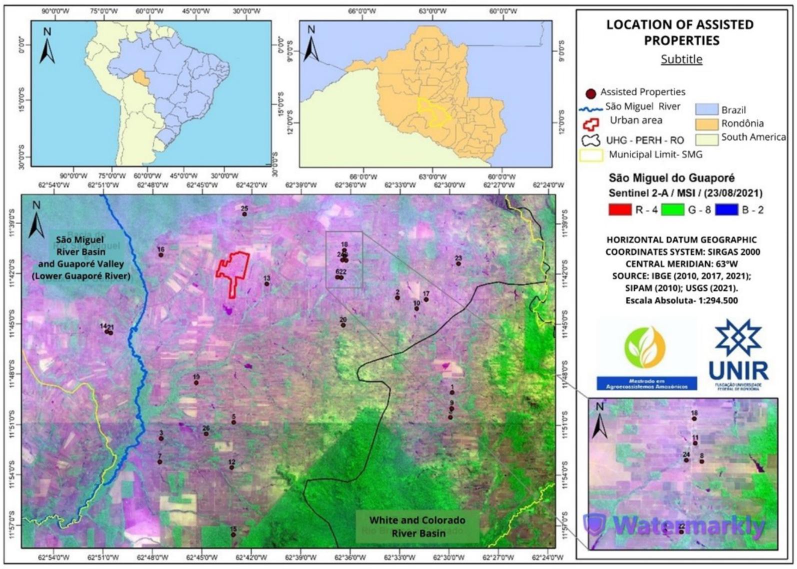

Figure 1. São Miguel do Guaporé– RO River Basin, and location of coffee producing properties in the area under study.
Source: The author.

The properties were chosen so that they met some requirements such as: Being part of the technical monitoring by ATEG; location (included in the hydrographic basin under study), have an established coffee growing activity and use irrigation in the crop, so that the study included 20 properties.

2.2. Descriptive research methods

A document analysis was carried out to delimit the object of study, followed by a descriptive research, where priority was given to the description in the form of quantification of variables studied in isolation. The data for identifying and selecting the properties to be studied were obtained by consulting the database provided by ATEG, responsible for monitoring coffee producing properties in the municipality of São Miguel do Guaporé, and data provided by the Soil, water and effluents Analysis Laboratory, Agri Lab.

Among the properties selected for the study, information was identified in the available database that helped in understanding the characteristics of the production process, such as: implanted culture; months in which irrigation is used; frequency of fertilization and fertilizers used, and source of water used to irrigate.

The visits to the selected properties (properties producing Robusta coffee located in the basin under study and with technical assistance from ATEG) were carried out with the aim of gathering information regarding the characteristics of the crop and the water sources used to irrigate the crop. Field research (Collection of samples) allowed us to learn about the characteristics of the properties to be studied, contact with the owners, collection of water to be analyzed, in order to respond to the objectives set. The results were approached in a qualitative and quantitative way through the presentation of numbers and concepts.

2.3. Water collection and analysis

The water samples were collected in November 2021, in 20 properties located in the Rio Branco Basin, in the Municipality of São Miguel do Guaporé, at a maximum depth of 0.30 m, at all points. After collection, the samples were stored in a Styrofoam box with ice and taken to the Soil, water and effluents Analysis Laboratory, Agrilab, located in the Municipality of Rolim de Moura-RO, and the samples arrived at the laboratory within 24 hours after collections. All water analyses were carried out according to the methodology of the Standard Methods for the Examination of Water and Wastewater (American Public Health Association, 2005).

The methodology used to carry out the water analyses was the Standard Methods 23rd Edition, evaluating the following parameters: pH, Conductivity, Color, Turbidity, Phosphorus, Total Hardness, Organic Matter, Total Solids, Sodium, Calcium, Magnesium (Baird et al., 2017). Na+ and K+ were determined spectrophotometrically. Ca, Mg, through titration. From the values of Na, Ca, Mg, the sodium adsorption ratio (SAR) was calculated, where the relationship between Sodium and Calcium and Magnesium is calculated, according to Equation 1 (Batista et al., 2016).

$$RAS = \frac{Na^{+}}{\sqrt{\frac{Ca^{+2}+Mg^{+2}}{2}}} \tag{1}$$

In this equation, all elements, namely Calcium (Ca), Magnesium (Mg) and Sodium (Na) must be inserted in mmolc L^{-1}. The salinity and sodicity indices for irrigation purposes used to interpret the data were in accordance with those established by Ayers & Westcot (1991).

2.4. Data analyses

Data processing was carried out in 3 stages: ordering, classification and finally, data analysis. In the data ordering stage, they were separated by coordinates, the quality and integrity of the data set was checked, eliminating discrepant results and detecting possible errors and inconsistencies occurring in the analytical procedures and methods. Afterwards, the results were classified according to the sequences in which they were performed.

To create the correlation matrix, the data were subjected to the Shapiro-Wilk normality test at 5% probability and since the data did not follow a normal distribution, they were correlated using the Spearman test using the Jamovi 2.2.5 program. After that, the data was classified using the significance test and discussion was carried out. Correlations with statistical significance were considered those with $p \leq 0.05$ and to classify the degree of correlation, the classification of Pearson's r and Spearman's p coefficients was used according to Mukaka (2012).

3. RESULT AND DISCUSSION

3.1. Characteristics of coffee-growing properties in the São Miguel do Guaporé river basin

On Table 1, information is presented that characterizes the coffee production systems of the properties under analysis, containing information about the irrigated crop such as: age, source of irrigation, fertilizers used, frequency and months in which irrigation is carried out, among others.

Table 1. Data on Robusta coffee (*Coffea conephora*) producing properties in the São Miguel do Guaporé– RO river basin.

N°	Irrigated crop	Age of crops	Source of water for irrigation	**Number of fertilizers** per year	**concentration Of NPK** used	Previous culture	Terrain relief
1	S	2	Dam	8	19-04-19	P	PL
2	S	2	Dam	8	19-04-19	P	PL
3	S	2,8	Dam	8	19-04-19	P	PL
4	S	2,9	Dam	6	19-04-19	M	PL
5	S	5	Dam	8	19-04-19	P	PL
6	S	4,10	Dam	8	19-04-19	P	PL
7	S	4	Dam	8	19-04-19	P	PL
8	S	2,8	Dam	8	19-04-19	P	PL
9	S	3,9	Dam	8	19-04-19	P	PL
10	S	2,9	River	5	19-04-19	P	PL
11	S	3,7	Dam	6	19-04-19	P	PL
12	S	3,9	water well	6	19-04-19	P	PL
13	S	5	Dam	5	19-04-19	M	PL
14	S	4	River	5	19-04-19	P	PL
15	S	4	Dam	8	19-04-19	P	PL
16	S	0,8	Dam	12	19-04-19	M	PL
17	S	5	Dam	8	19-04-19	P	PL
18	S	4,8	Dam	8	19-04-19	P	PL
19	S	5	water well	8	19-04-19	C.A	PL
20	S	4,8	water well	6	19-04-19	P	PL

S:yes / P: Pasture / PL: Flat land / C.A: Culture Annuals/ M: Florest

Source: Prepared by the author, with data provided by ATEG

According to the data in Table 1, all coffee producing properties included in the scope of the research are irrigated. According to information collected by ATEG (Technical and Management Assistance), irrigation occurs between the months of July and September, a period characterized as dry in the region and 75% of the water used to irrigate comes from dams.

The age of the crops varies from 8 months to five years, and all are fertilized with NPK 19-04-19, with the aim of providing Nitrogen, Phosphorus and Potassium. All properties have almost no relief in the planting area, which facilitates crop management and the operation of the irrigation system. Regarding the previous history of the area, it can be observed that 78% of the current crop areas were previously used for pasture.

In relation to the high percentage of crops implemented that were previously pastures, in accordance with Becker (1966) apud Costa (2004), livestock farmers at the time resorted to the extensive way of conquering new spaces, through the formation of pastures in areas of virgin forest, not suitable for agriculture. Costa (2004) also states that in the last three decades, beef and dairy farming has still experienced extraordinary growth in Rondônia, having expanded at a rate of 22% per year in the last decade. In the last ten years (2009-2019), the growth of the cattle herd was more gradual, when compared to the beginning of this exploration, even so, a growth of around 26.0% was observed (Associação Brasileira de Indústrias Exportadoras de Carne, 2019)

In addition to beef cattle farming, there is also the importance of dairy farming in Rondônia, being the largest milk producer in the Northern Region of Brazil (Empresa Brasileira de Pesquisa Agropecuária, 2021), responsible for 47.0% of the production (Instituto Brasileiro de Geografia e Estatística, 2017). Rondônia is the eighth largest milk producer in Brazil (Secretaria de Estado da Agricultura, 2018).

Since Rondônia contains a large part of the territory that is made up of pastures, in recent years the indication for the intercropping of coffee cultivation with pastures has been recommended, as it reduces the evaporation of water from the soil, maintaining humidity and reducing heating by solar rays (Bonissoni, 2020). However, on the properties under study, what was observed in situ was the replacement of pasture by coffee crops.

Regarding the water used on properties, the main source comes from dams, representing 75% of properties, followed by water from wells and rivers, and approximately 15% of these presented abnormal characteristics in the water supplied, such as the presence of rust.

Properties that have a well as a source of water supply for crop irrigation are properties that do not have rivers and dams near the cultivated area or even on their property.

In the State, SEDAM is the government body responsible for the qualitative and quantitative inspection and analysis of water resources and, consequently, the Granting of the Right to Use Water Resources. As indicated in Article 4 of Ordinance GAB/SEDAM No. 081, of March 23, 2017, all uses and interventions that alter the natural course of water bodies will depend on the Grant of the Right to Use Water Resources, issued by SEDAM, or its quantitative or qualitative conditions, one of these examples is the capture of surface water or underground aquifer for final consumption, including for public supply or production process input (Secretaria de Estado do Desenvolvimento Ambiental, 2017).

Regarding the use of water resources for irrigation, although Complementary Law nº 255, of January 25, 2002, regulates the Granting of the Right to Use Water Resources in the state of Rondônia, 46% of the coffee growers interviewed in the Ribeirão Cacau microbasin still do not have access to the same, but 27% have already started the process for release (Silva, 2020). Despite the above, 73% of the producers interviewed have a Permanent Preservation Area on their properties, 64% participate in the Coffee Geographical Indications Program and 45.4% show concern about the region's future in regard to water (Silva, 2020).

Espíndula et al. (2017), state that the municipality of São Miguel do Guaporé stood out for having the largest cultivation area in the state at the time of their research. They also state that the months of June, July and August are the driest months in the state and the accumulated precipitation hardly exceeds 50 mm (in a region where, during rainy season, it exceeds 700 mm), in the municipalities of the central region and southwest of Rondônia, which justifies the use of irrigation.

3.2. Water quality analysis

The results regarding the quality of water samples collected from samples, taken from 20 coffee-growing properties located in the São Miguel do Guaporé River basin, are shown in Table 2, along with reference values identified in the literature, for irrigation. In addition to the authors mentioned, CONAMA resolution 357 of 2005 was considered as the main reference standard for class 3 fresh waters: waters that can be used "for the irrigation of tree, cereal and forage crops" (Brasil, 2005).

Table 2. Minimum, average and maximum values of the analytical results of water samples in Robusta coffee (*Coffea conephora*) producing properties located in the São Miguel do Guaporé river basin - RO and reference values

Parameter	UN	Mín.	Máx.	Average	Reference values (*CONAMA)	Reference values (Irrigation)	Authors
pH	pH a 25 °C	5,2	6,5	5,9	6,0 - 9,0	6,50 - 8,40	Junior (2020)
Total hosphorus	$mg.L^{-1}$	0,0	18,5	6,2	0,05 mg/L P	< 2,00 mg/L	Von Sperling (2005)
Total hardness	$mg.L^{-1}$	0,0	88,0	17,2	-	<5,00 mmol/L (Ca+Mg) ou <90,09 mg/L	Ayers & Westcot (1999)
Calcium	$mg.L^{-1}$	0,0	16,8	4,0	-	---	---
Magnesium	$mg.L^{-1}$	0,0	14,6	11,0	-	---	---
CE	µS/cm	0,0	111,5	20,7	-	---	---
Color	Pt/Co	0,0	918,0	170,1	until 75 mg Pt/L	---	---
Sodium	$mg.L^{-1}$	0,7	1,0	1,4	-	<8,70	Canovas Cuenca (1980)
Turbidity	NTU	0,0	127,0	26,7	100 UNT	---	---
Total solids	$mg.L^{-1}$	7,0	37,0	26,4	500 mg/L	450 mg/L	Almeida (2010)

*The standards considered were Class 3 (CONAMA 357 of 2005), according to the use "irrigation of tree crops".
Source: The author.

It is possible to observe that the parameters analyzed present very different values within the same basin, making it extremely important to carry out analyses whenever an irrigation system is implemented on a given property.

3.2.1. pH (Hydrogenionic Potential)

The pH is an important factor in evaluating the quality of water for irrigation, as it characterizes the degree of acidity or alkalinity of the water or soil. In the case of water for irrigation, the indicated pH is between 6.0 and 9.0; this reference value is determined in CONAMA 357/2005.

Junior (2020), states that water with a pH above 8.4 can cause blockages in irrigation systems, due to the precipitation of calcium carbonate ($CaCO3$). On the other hand, water with low pH values can quickly corrode the metallic components of the sprinkler irrigation system (Junior, 2020).

The pH of the samples evaluated varied between 5.2 and 6.5 and of the 20 samples analyzed, 11 presented results within the limit established by CONAMA 357/2005, totaling 55% of the samples.

Gómez Lucas & Pedreño (1992) state that a pH outside the recommended range for irrigation can be an indicator of the presence of a toxic ion, which can cause problems for the soil's microbial population, in addition to altering existing balances in the soil and even damaging the plant's root system.

3.2.2. Phosphorus

Phosphorus is an element of great importance for studies related to irrigation quality. Ayers & Westcot (1999) consider this parameter an interference factor for water intended for agricultural use, and according to Von Sperling (2005) agriculture is the main polluting source of phosphorus in surface waters.

According to both authors, the phosphorus concentration rate in water used in agriculture cannot exceed 2 mg. L^{-1}. The samples analyzed presented a phosphorus value of 0 to 18.5 mg. L^{-1}, with around 30% of these waters having phosphorus within the limit that these authors provide.

The authors above cite reference values for phosphorus that can be used for irrigation in agriculture other than CONAMA 375/2005, which mentions values well below those of the authors, establishing a maximum value of 0.05 mg. L^{-1} of total phosphorus for lentic environments, i.e., dams.

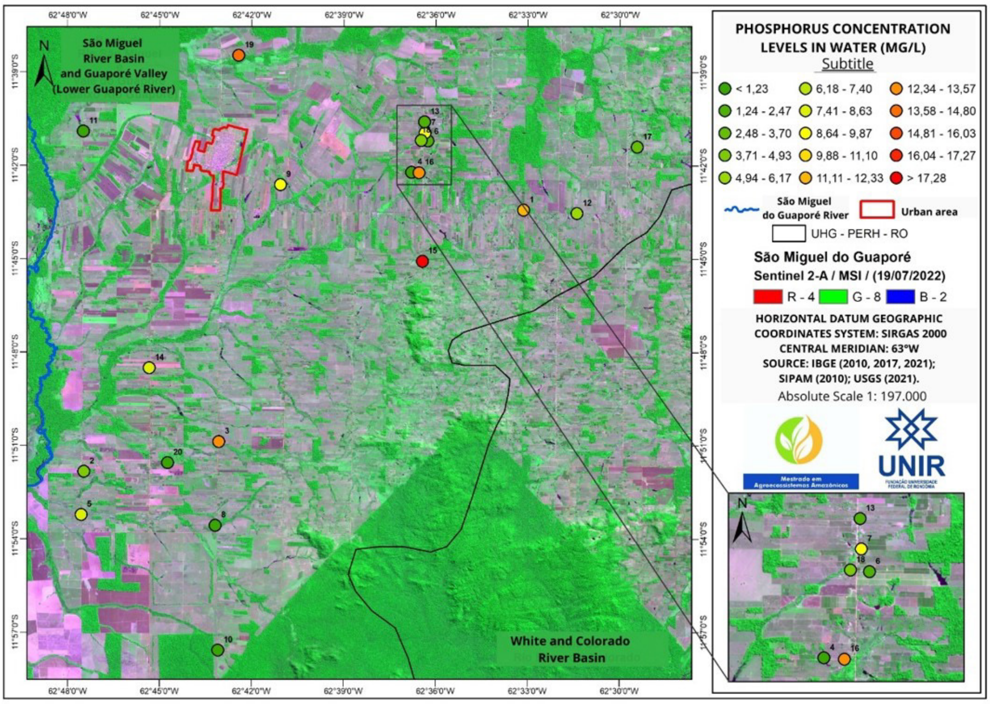

Figure 2. Spatialization of phosphorus in water.
Source: The author.

In the samples evaluated, only 4 of the 20 samples presented values within the limit established by CONAMA 357/2005 (Figure 2). It is worth noting that the period under analysis was the rainy season, and, given the seasonal differences that may occur in nutrient concentrations in water bodies, it is important to evaluate this parameter also during the dry period, in order to adopt more assertive measures.

Barbosa & Silva Filho (2018) identified phosphorus values in the Pirarara River Basin, located in the municipality of Cacoal-RO, ranging from 0.8 to 2.6, values that also do not fit within those established by CONAMA 357/2005.

Although there are no dumps of industrial effluents at these points under study, the increase in phosphorus levels in the water may be due to the use of chemical products (fertilizers) rich in phosphorus used in agriculture, and during the rainy season they are carried to the course of the river, raising the averages significantly.

Silva (2018) states that the analyses carried out on water samples from the igarapé Dois de Abril river basin, in the municipality of Ji-Paraná/RO, showed phosphorus values of 0.05 to 2.58 mg. L^{-1} in the dry period and 0.00 to 2.31 mg. L^{-1} during the rainy season.

3.2.3. Total Hardness

The total hardness of water is the sum of the concentrations of Calcium and Magnesium present in the sample (Figures 3 and 4, respectively), and through this we can classify the water as: very sweet, sweet, moderately sweet, moderately hard, hard and very hard. Ayers & Westcot (1999), limits the value of 5.0 mmolc L^{-1} for Ca+2+Mg+2 to be used in irrigation, eliminating, that way, the risk of incrustations in equipment and pipes. In this study, the values are below the established limit, with the majority of points being classified as very sweet, not causing any problems regarding hardness.

The total hardness of the samples analyzed presented concentrations between 0.00 and 88.00 mg. $L^{-1,}$ in $CaCO_3$ remaining very close to the results obtained by Nascimento et al. (2011) in which total hardness values were found to vary between 0 and 100 mg. L^{-1} in CaCO3 in water from wells located in the Jamari and Machado river basins, in the state of Rondônia.

3.2.4. Calcium and Magnesium

The lowest calcium results presented in the water samples analyzed were in properties 3, 5, 9 and 16 (Figure 3), all of which have irrigation from dams. Magnesium is also related to calcium and remains lower in properties 3, 5, 16 and 18 (Figure 4). Due to the low amount of calcium and magnesium, these waters are classified as very sweet, as previously discussed.

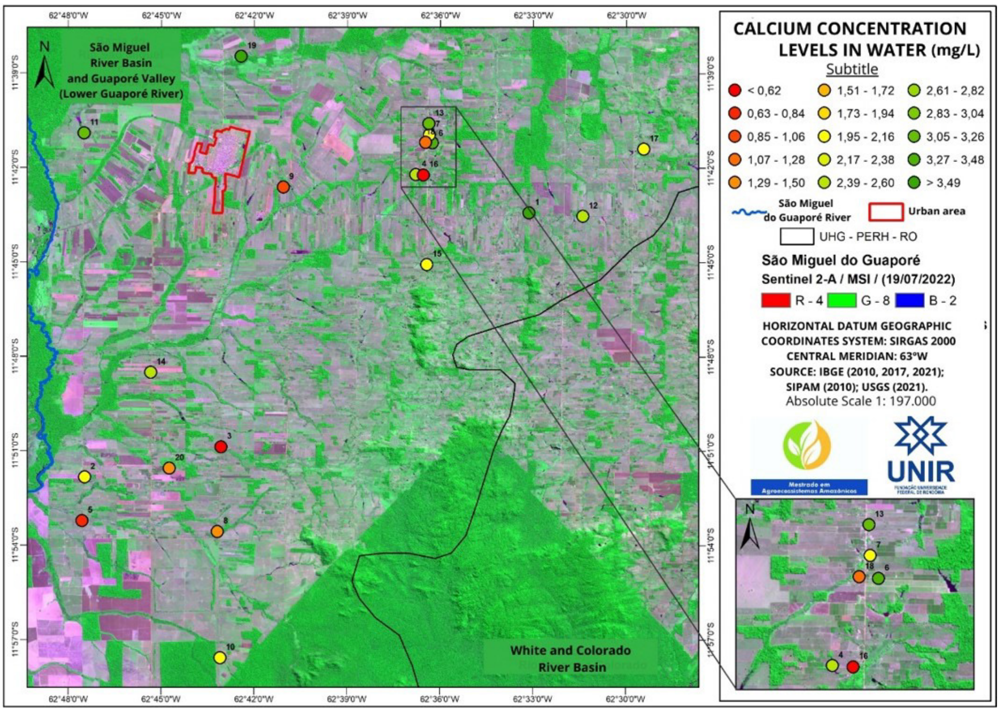

Figure 3. Spatialization of calcium in water.
Source: The author.

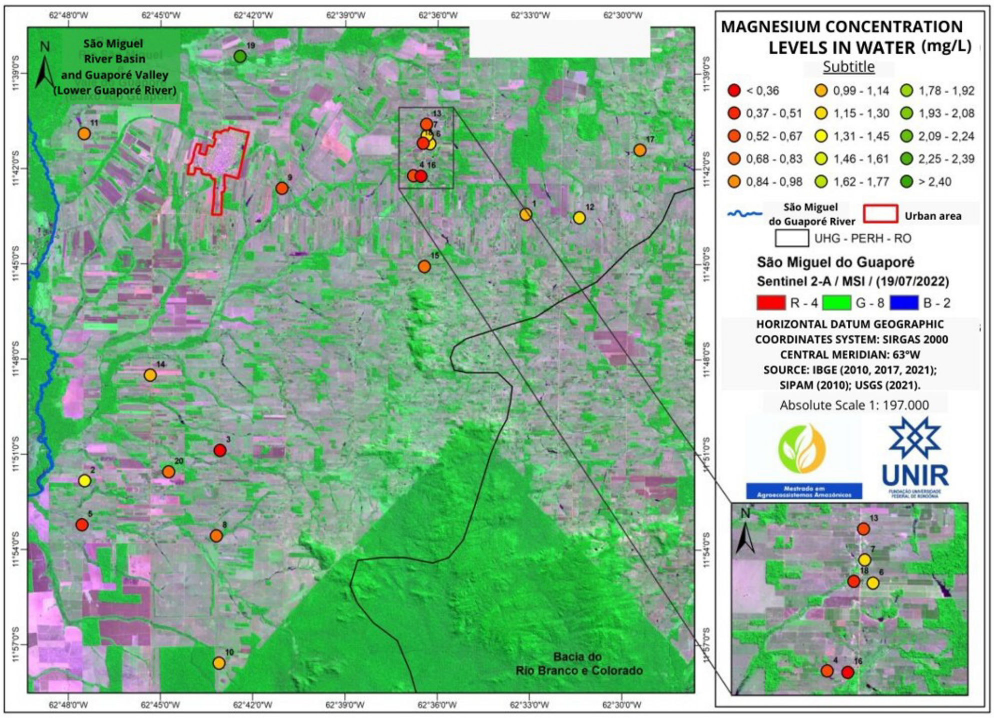

Figure 4. Spatialization of Magnesium in water.
Source: The author.

3.2.5. Electrical Conductivity

Regarding the electrical conductivity of the water samples evaluated, values ranging from 4.5 to 111.5 uS/cm (or, 0.01 to 0.11 dS/m) were found. Although CONAMA resolution 357/05 does not recommend acceptable conductivity limits, this parameter is widely used to evaluate irrigation water, as it is easy and low-cost, and allows the amount of salts to be assessed, given that the higher the content saline solution of a larger solution will be its conductivity (Almeida, 2010).

Nakai et al. (2013) collected water samples at five points on the São Francisco Falso-Braço Sul River, in different seasons of the year, so that results could be compared in the dry, rainy and intermediate periods, and the EC of the water samples varied from 0.06 to 0.07 dS m^{-1}, with an average of 0.061 dS m^{-1} during the dry season and from 0.06 to 0.1 dS m^{-1}, with an average of 0.079 dS m^{-1} during the rainy season, and 0 .07 to 0.09, with an average of 0.078 dS m^{-1} in the intermediate period, similar to the result found in the present study.

According to Esteves (1998) electrical conductivity can inform ionic concentration and geochemical differences in a river basin and help detect polluting sources in aquatic ecosystems; conductivity indicates changes in the composition of a water, especially its mineral concentration, but does not provide any indication of the relative quantities of the various components (Companhia Tecnológica de Saneamento Ambiental, 2005).

3.2.6. Salinity

To evaluate the salinity class of water to be used for irrigation, it is normally evaluated based on the water's electrical conductivity (EC). Almeida (2010), states that water with values lower than 0.75 dS m^{-1}, or < 450 mg L^{-1} of total dissolved salts (TDS) does not present restrictions on use for irrigation, given the result found, it can be stated that all measured values are within acceptable standards for irrigation.

All samples analyzed were classified within the C1 classification, regarding the risk of Salinity, based on data published by Ayers & Westcot (1991), as they presented electrical conductivity lower than 0.7 dS m^{-1}, as shown in Figure 5.

In turn, Pizarro (1985) states that when the salinity of irrigation water is very low, there is a high risk of sodicity, even at very low values of Sodium Adsorption Ratio - SAR°.

The same author highlights that conductivity lower than 0.2 dS m^{-1} causes irrigation waters to cause problems and sodicity regardless of the Sodium Adsorption Ratio-SAR° value. Therefore, even if within the salinity parameters presented by Ayers & Westcot (1991), the waters of the São Miguel do

Guaporé River basin are not at risk of causing any salinity problem, however, when associated with sodicity, it brings great concern to the researcher. Pizarro (1985) states that for this reason rainwater can be the cause of the dispersion of colloids on the soil surface, with its resulting problems: loss of structure, impermeability, high runoff, erosion, etc.

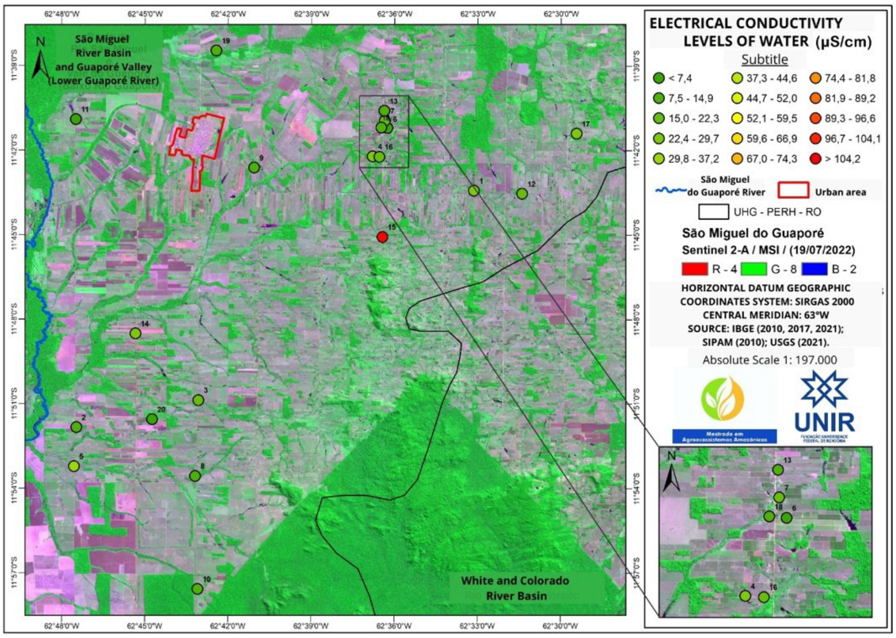

Figure 5. Spatialization of electrical conductivity in water.
Source: The author.

3.2.7. Sodium Adsorption Ratio

The SAR (Sodium Adsorption Ratio) is the assessment of the relative proportion in which sodium is found in relation to the total calcium and magnesium present in the water (Almeida, 2010), this value is not a parameter present in the CONAMA resolution 357 of 2005, but it is an important factor to be observed when water is intended for irrigation purposes, as, combined with the electrical conductivity of the water, it can cause severe restrictions regarding its use (Batista et al., 2016).

The SAR of the analyzed samples when evaluated alone does not present any risk of causing problems in irrigation or in the soil, however, when associated with EC, it presents problems that must be highlighted.

The waters of the São Miguel do Guaporé river basin are classified in terms of salinity and sodicity as C1S3; where C1 means that it does not present any risk of salinity and S3 means that it presents a severe problem in terms of infiltration problems into the soil due to the sodicity of the water. The increase in sodicity occurred due to low concentrations of total salts (EC) and not due to high SAR values.

A soil's ability to absorb water increases as its salinity increases and decreases when the sodium adsorption ratio (SAR) increases or when its salinity decreases (Bernardo et al., 2006; Gheyi et al., 2016) . With this we understand that even if there is no amount of Sodium capable of causing problems analyzed alone, this becomes worrying since the salinity value of these waters is very low, thus causing a decrease in the infiltration rate of these soils. Therefore, the two attributes, SAR and salinity, must be analyzed together to be able to correctly evaluate the effects of irrigation water on reducing the infiltration capacity of a soil.

The classification of irrigation waters in relation to RAS is essentially based on the effect of Na^+ on the physical conditions of the soil, causing infiltration problems due to reduced permeability (Holanda et al., 2016).

Other authors (Amorim et al., 2008; Andrade Júnior et al., 2006), also recommend the use of the electrical conductivity of irrigation water (EC) associated with SAR to assess the risk of reducing water infiltration capacity in the soil, as the salts present in the soil solution have a flocculating effect, as opposed to the dispersing effect of exchangeable sodium; therefore, for the same SAR value, the risk of sodicity will be lower the higher the water conductivity.

When relating SAR to the salinity of irrigation water, the results indicate a severe restriction of use related to infiltration problems. According to Scaloppi & Britto (1986), waters with an EC of less than 500 µS.cm^{-1} and, particularly, below 200 µS.cm^{-1} have the tendency to leach soluble salts and minerals, including calcium, reducing their influence on the stability of aggregates and soil structure. Therefore, when the infiltration problems present in irrigated areas are not caused by the effect of high SAR, they are invariably caused by very low salinity waters, justifying, that way, the results found.

Zamberlan (2007) carried out a study in four surface springs belonging to the Federal University of Santa Maria-RS that have potential water for irrigation use and it also presented a severe restriction on the use of its water for irrigation due to the low value of electrical conductivity when related to the low SAR values. Regardless of the SAR value, waters with very low electrical conductivity, lower than 0,2 dS m^{-1}, can cause infiltration problems (Ayers & Westcot, 1991).

In general, Zamberlan (2007) states that the risk of soil salinization, when using water from the four reservoirs, is small and problems could only occur with the infiltration capacity, which is perfectly overcome by applying a source of calcium. on the ground.

As the source of calcium is an alternative that can also be used in the São Miguel do Guaporé river basin, since the soils in the region also require these calcium corrections frequently.

Since the samples analyzed were only carried out during the rainy season, the search for literature to better understand these results is still necessary, but a study carried out in Queimadas-PB in 2016 states that in all months of the year, the standard deviation of calcium it was just 0.7 over the 12 months, magnesium was 2.1; dos was 4.4; electrical conductivity 0.8 and pH showed only 0.4 standard deviation (Lima Junior et al., 2017).

Lima Junior et al. (2017) state that, despite the low values for the standard deviation, a change was observed in the class regarding the risk of salinity and sodicity, where the water went from C3S1 (January) to C4S2 (April), thus indicating its degradation. This occurred during the period of scarcity of precipitation, when irrigation was full.

3.2.7. Turbidity

Regarding turbidity, CONAMA 357/2005 establishes reference values of up to 100 UNT so that the water can be used for irrigation. Of the samples analyzed, only one is outside the values allowed by the aforementioned resolution.

3.2.8. Total Dissolved Solids

CONAMA 357/2005 recommends that total dissolved solids cannot exceed the 500 mg. L^{-1} in waters intended for irrigation. No sample analyzed in the São Miguel do Guaporé river basin presented values that were not adequate, the samples varied from 7.00 to 37.00 mg. L^{-1} presenting values well below the maximum limit of CONAMA 357/2005.

It is desirable that turbidity and total solids analyzes present values within the permitted range, as the presence of total solids dissolved in water is associated with organic and inorganic micropollutants, with emphasis on heavy metals due to their toxicity, among others. In turn, excessive turbidity can reduce light penetration, damaging photosynthesis (oxygenation) of water bodies, among other problems (Chagas, 2015).

There was no difference in the quality of water from the three types of origin (dam, well and river) used for irrigation of coffee growing in the São Miguel do Guaporé river basin, one of the only differences that can be noticed is that, of the three wells used, two of them showed a color equal to zero, while none of the other systems showed this result. Furthermore, the total dissolved solids of water that originated from wells also showed lower results.

Knowing the water quality of the São Miguel do Guaporé- RO river basin is, therefore, relevant, since food production depends on these components.

3.2.9. Spearman correlation analysis

In Table 3, the results of the Spearman correlation analysis for water quality data are presented.

Spearman's correlation is a non-parametric statistical test that measures the dependence between ranks of two variables. The relationship between the two variables varies between -1 to +1, the closer to this number the greater the strength of the relationship between variables. Values close to 0 indicate weaker or non-existent correlations. If the Spearman correlation result is positive, it means that the increase in one variable is associated with the increase in the other variable. When the correlation values are negative, they indicate that the increase in one variable is associated with a decrease in the other (Lima, 2021).

Electrical conductivity and calcium present in water showed a moderate and positive interaction, that is, increasing the content of one of these in the soil will increase the content of the other as well. The electrical conductivity of irrigation water (EC) basically considers the total amount of salts present in the water, without specifying them (Almeida, 2010).

Calcium and magnesium interact positively on a strong scale with Hardness. This happens because the main metallic ions that give water hardness are calcium (Ca^{2+}) and magnesium (Mg^{2+}), associated with the sulfate ion (SO4) $^{2-}$ (Moreira, 2001).

As previously mentioned, hardness consists of the concentration of alkaline earth ions, more specifically calcium and magnesium, as these are found in higher concentrations than the others, hardness can cause problems such as scale (Almeida, 2010). However, even though the positive correlation between the levels of Calcium, Magnesium and the hardness of the water samples in the São Miguel River basin was positive, these waters are classified as very sweet as previously discussed due to the low amount of calcium and magnesium present in the same.

Hardness also has a moderate interaction with electrical conductivity and color, and in turn, color and calcium also have a moderate interaction. This interaction of color with calcium occurs because the color of water comes from dissolved substances (Moreira, 2001).

Table 3. Spearman correlation matrix between water quality parameters in the São Miguel do Guaporé-RO river basin.

		Ca	CE	Cor	D	P	Mg	M.O	pH	Na	S	T
Ca	Spearman	_										
	p-value	_										
CE	Spearman	0,597	_									
	p-value	0,005	_									
Cor	Spearman	0,69	0,484	_								
	p-value	<,001	0,031	_								
D	Spearman	0,834	0,6	0,526	_							
	p-value	<,001	0,005	0,017	_							
P	Spearman	0,281	0,503	0,047	0,467	_						
	p-value	0,231	0,024	0,842	0,038	_						
Mg	Spearman	0,482	0,352	0,373	0,794	0,344	_					
	p-value	0,031	0,128	0,105	<,001	0,137	_					
M.O	Spearman	0,382	0,213	0,607	0,163	-0,324	0,106	_				
	p-value	0,097	0,367	0,005	0,493	0,163	0,657	_				
pH	Spearman	0,397	0,383	0,647	0,396	0,282	0,302	0,17	_			
	p-value	0,083	0,095	0,002	0,084	0,229	0,195	0,474	_			
Na	Spearman	0,364	0,622	0,266	0,555	0,555	0,511	0,114	0,385	_		
	p-value	0,114	0,003	0,256	0,011	0,011	0,021	0,633	0,093	_		
S	Spearman	0,822	0,394	0,816	0,637	0,025	0,383	0,529	0,498	0,136	_	
	p-value	<,001	0,085	<,001	0,003	0,917	0,096	0,016	0,026	569	_	
T	Spearman	0,448	0,254	0,79	0,306	0,064	0,18	0,175	0,721	-0,002	0,65	_
	p-value	0,048	0,281	<,001	0,189	0,788	0,448	0,46	<,001	0,992	0,002	_

D: Hardness / S: Solids / T: Turbidity

Source: The author.

Turbidity interacts with several analyzed parameters such as calcium, color, pH and solids. These interactions occur because turbidity is the attenuation that a light beam undergoes when passing through a sample, that is, the greater the number of particles in the sample, the greater the scattering of light and greater turbidity (Rocha, 2019). Thus, we can also justify the interaction of solids with the level of calcium, color, hardness and O.M., because even though they do not generate particles directly in the water, they interact with parameters that increase the number of particles in the sample. The existing correlation between the turbidity variable and Color was also observed in work carried out by Seben et al. (2021), as well as the calcium variable and turbidity.

Sodium showed a moderate and positive interaction with several parameters, including electrical conductivity, hardness, phosphorus and organic matter. By changing the pH-alkalinity-carbon dioxide balance, calcium carbonate can precipitate, decreasing calcium and total hardness values (Almeida, 2010).

Calcium, both in soil and water, has the function of correcting pH, neutralizing the toxicity of some elements (Al, Mn, Na and Mg) and reducing the sodium adsorption ratio (SAR), thus providing better soil structural stability (Ayers & Westcot, 1991). On Table 3 it is possible to observe that Ca and Mg, although weak, interact with each other, as do phosphorus and hardness.

When analyzing the chemical characteristics of the waters that are being used for fertigation of these soils, it is observed that there is no risk of precipitation from phosphate fertilizers, as the amount of calcium present in these waters is too low for this to occur.

Urea ($-NH_2$) is one of the fertilizers that should be avoided using in soils that are already acidic as it causes an acidifying effect on the soil. However, because most of the waters are acidic, there is no limitation on the use of DAP, (Diammonium Phosphate Fertilizer), however, if there is Ca and the pH is greater than 7, MAP (Monoammonium Phosphate Fertilizer) must be used, which has an effect acidifying, which leads to a lowering of pH. Another possibility is the use of concentrated phosphoric acid. The amount applied must be sufficient to lower the pH of the soil and water, however, there is a limit so that it does not produce corrosion in metal parts of the network (Pereira & Melo, 2003).

The smallest discrepant variation of attributes was verified for electrical conductivity, and when evaluating all parameters it is clear that this property presented reasonable values for calcium and magnesium, justifying the value obtained.

4. FINAL REMARKS

1. Information about irrigation: Irrigation of Robusta coffee (Coffea conephora) crops assisted by the National Rural Learning Service-SENAR–RO program located in the São Miguel do Guaporé River basin occurs between the months of July to September and around 75% of water used for irrigation comes from dams.

2. Water quality: Water quality analyzes showed that most of the samples have a pH close to that recommended by the researchers, and within the limits established by CONAMA 357, and around 30% of the samples have phosphorus within the desired range, with their classification regarding salinity and sodicity in C1S3, highlighting the need for adequate management.

3. Water use and need for studies: Despite some non-standard parameters, water can be used following management criteria, highlighting the importance of new studies during the dry period to better understand these variables and assist in the conservation of water resources.

5. ACKNOWLEDGMENTS

The authors would like to thank CAPES for the funding (Notice No. 13/2020 – Postgraduate Development Program – Legal Amazon), and the Federal University of Rondônia (UNIR), through the Postgraduate Program in Amazonian Agroecosystems (PPG -AA).

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Author contributions:

Andressa dos Santos Cruz: choice of the method used for laboratory analysis, choice of the area to be studied, collection of samples in the field, laboratory analysis, writing of the Methodological Review and discussion of the results.

Nara Luisa Reis de Andrade: guidance, monitoring throughout the field and laboratory research period, methodological review and textual and discussion contributions.

Adjalma Campos de França Neto: methodological review and textual and discussion contributions.

Jeferson Alberto de Lima: methodological review and textual and discussion contributions.