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ARTICLE

SEASONAL ANALYSIS OF AQUATIC WATER QUALITY IN A FORESTRY AREA, MS, BRAZIL

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Abstract

Water quality is one of the topics of greatest concern worldwide, as it is a fundamental resource for life, whose constant monitoring is necessary. The objective of this work was to carry out seasonal monitoring of water quality in the Urutu-MS stream, occupied by more than 50% of eucalyptus silviculture forests. Water samples were collected from five points seasonally between autumn 2019 and summer 2020. Twenty-three parameters included such as temperature, pH, Dissolved oxygen, Conductivity, Alkalinity, Organic matter, Chloride, Sulfate, Total iron, Color, Turbidity, Total dissolved solids, Total suspended solids, Chemical Oxygen Demand, Total phosphorus, Hardness, Aluminum, Manganese, Magnesium, Sodium, Calcium, Copper and Dissolved Iron. The results showed that there is a difference in water quality between the seasons due to the different concentrations of physicochemical parameters. Spring was in class II, while the others were in class I, showing the influence of the onset of rain after the dry winter. Interactions between parameters followed conventional associations such as Alkalinity and Conductivity, SDT and Conductivity, Color and Turbidity, SST and Turbidity, Conductivity and Calcium, Conductivity and Magnesium. Alkalinity and TDS being the main parameters influenced by seasonality.

Keywords: Paraná Watershed, Land use and Land Cover, Cerrado, Silviculture, Seasonality.

Resumo / Résumé

ANÁLISE SAZONAL DA QUALIDADE DA ÁGUA AQUÁTICA EM UMA ÁREA FLORESTAL, MS, BRASIL

Qualidade da água é um dos temas de maior preocupação mundial, pois se trata de um recurso fundamental a vida, cujo monitoramento constante se faz necessário. O objetivo deste trabalho foi realizar o monitoramento sazonal da qualidade água no córrego Urutu-MS, ocupada em mais de 50% com florestas de silvicultura de eucalipto. As amostras de água foram coletadas de cinco pontos sazonalmente entre o outono de 2019 e o verão de 2020. Sendo vinte e três parâmetros inclusos como temperatura, pH, Oxigênio dissolvido, Condutividade, Alcalinidade, Matéria Orgânica, Cloreto, Sulfato, Ferro total, Cor, Turbidez, Sólidos dissolvidos totais, Sólidos suspensos totais, Demanda Química de Oxigênio, Fósforo total, Dureza, Alumínio, Manganês, Magnésio, Sódio, Cálcio, Cobre e Ferro Dissolvido. Os resultados mostraram que há diferença na qualidade da água entre as estações do ano em função das diferentes concentrações dos parâmetros físico-químicos. A primavera apresentou-se na classe II, enquanto as demais na classe I mostrando a influência do início das chuvas após o inverno seco. Interações entre os parâmetros obedeceram às associações convencionais como Alcalinidade e Condutividade, SDT e Condutividade, Cor e Turbidez, SST e Turbidez, Condutividade e Cálcio, Condutividade e Magnésio. Sendo a Alcalinidade e SDT os principais parâmetros com influência da sazonalidade.

Palavras-chave: Bacia Hidrográfica do Paraná, Uso e Cobertura da Terra, Cerrado, Silvicultura, Sazonalidade.

ANALYSE SAISONNIÈRE DE LA QUALITÉ DE L'EAU AQUATIQUE DANS UNE ZONE FORESTIÈRE, MS, BRÉSIL

La qualité de l’eau est l’un des sujets les plus préoccupants à l’échelle mondiale, car il s’agit d’une ressource fondamentale pour la vie, nécessitant une surveillance constante. L'objectif de ce travail était de réaliser un suivi saisonnier de la qualité de l'eau du ruisseau Urutu-MS, occupé à plus de 50% par des forêts sylvicoles d'eucalyptus. Des échantillons d'eau ont été collectés en cinq points de manière saisonnière entre l'automne 2019 et l'été 2020. Vingt-trois paramètres ont été inclus, tels que la température, le pH, l'oxygène dissous, la conductivité, l'alcalinité, la matière organique, le chlorure, le sulfate, le fer total, la couleur, la turbidité, les solides dissous totaux, les matières en suspension totales, la demande chimique en oxygène, le phosphore total, la dureté, l'aluminium, le manganèse, le magnésium, le sodium, le calcium, le cuivre et le fer dissous. Les résultats ont montré qu’il existe une différence de qualité de l’eau entre les saisons en raison des différentes concentrations de paramètres physico-chimiques. Le printemps a été classé en Classe II, tandis que les autres saisons étaient classées en Classe I, montrant l'influence de l'arrivée des pluies après l'hiver sec. Les interactions entre les paramètres suivaient des associations conventionnelles, telles qu'entre l'alcalinité et la conductivité, les SDT et la conductivité, la couleur et la turbidité, les SST et la turbidité, la conductivité et le calcium, et la conductivité et le magnésium. L'alcalinité et les SDT étaient les principaux paramètres influencés par la saisonnalité.

Mots-clés: Bassin versant du Paraná, Utilisation des terres et couverture des terres, Cerrado, Sylviculture, Saisonnalité.

ARTICLE

INTRODUCTION

Water quality is one of the most critical global topics (BILGIN, 2018; ZHANG et al., 2018; ABBOTT et al., 2019; GAYTÁN-ALARCÓN et al., 2022) due to its numerous functionalities. Human consumption, agriculture, animal watering, industrial use, and mainly environmental conservation can be mentioned (SHI et al., 2017; ZHANG et al., 2019; GOMES et al., 2020) as water can show changes in the environment, constituting a necessary tool for environmental monitoring.

In this context, water quality monitoring is an essential tool used in several studies (ANDRIETTI et al., 2016; AMÂNCIO et al., 2018; SOLDÁN, 2021; OLIVEIRA et al., 2022; GIAO, 2022) to control potential risks to human health (ISLAM et al., 2020), as well as in environmental assessment, also functioning as a water resource management tool.

According to Tucci (1997), water quality is influenced by numerous factors, such as geology, soil, land use and land cover, geomorphology, and climate, and each water system has its particularities. Li et al. (2015) point out that the influence of climatic seasonality due to different rainfall patterns can affect water quality, which is corroborated by several studies in the academic literature (SHI et al., 2017; ZHANG et al., 2017; BHATTI et al., 2018; MOHSENI-BANDPEI et al., 2018; YEVENES et al., 2018; WEI et al., 2018). In addition, there is evidence indicating that seasons have specific characteristics that can disturb surface water quality (ZHONG et al., 2018).

Thus, water quality reflects the characteristics and interactions of the environment (HUNG et al., 2020; XU et al., 2020), as there is evidence that water quality in watersheds can be affected by the disposition of vegetation cover (SHI et al., 2017; GOMES et al., 2020). Therefore, water quality analysis is an essential tool for environmental planning of watersheds (FU et al., 2022).

In this way, environmental changes provided by land use and land cover can bring considerable social and economic benefits, as is the case of planted forests that currently represent 7% of the world's forest area (FAO, 2020), in Brazil in 2020 amounted to 9.55 million hectares, with a total of 1.12 million hectares in the state of Mato Grosso do Sul alone (IBÁ, 2021). But can cause damage to the components of the hydrological cycle (TANIWAKI et al., 2017; BIRHANU et al., 2019) in the displacement of significant chemical and physical elements to water bodies (PACHECO and FERNANDES, 2016; Gomes et al., 2020), due to management, harvesting and other forest operations in the maintenance of silviculture (BAILLIE and NEARY, 2015; RODRIGUES et al., 2019).

To guarantee water quality and quantity, the National Water Resources Policy was also instituted in Brazil under Law 9.433/97 (BRASIL, 1997) to ensure water availability for current and future generations. Another concern in this regard refers to the establishment of water quality standards, which created a legal instrument through the Ministry of the Environment (MMA), via the National Environment Council (CONAMA), which developed Resolution No. 357 of 17 March 2005, functioning as a guideline in the assessment of water quality conditions (BRASIL, 2005). Several studies in the literature demonstrate the satisfactory applicability of this resolution as a parameter in monitoring water quality (LELIS et al., 2015; THOMPSON et al., 2020; BERLANDA et al., 2021). However, there needs to be more literature focusing on seasonal monitoring of surface water quality in watersheds in areas heavily occupied by silviculture. Thus, the present work aims to carry out the seasonal monitoring of the surface water quality of the Urutu watershed (UW) in the municipality of Aparecida do Taboado-MS, Brazil, based on the parameters established by the CONAMA Resolution 357/2005 (Brazil, 2005), followed by CECA/MS Deliberation No. 36/2012 (MATO GROSSO DO SUL, 2012) and CERH/MS Resolution No. 52/2018 (Mato Grosso do Sul, 2018), as a subsidy for the implementation of monitoring local seasonality of water quality, as well as enabling the construction of an additional component variable in future studies of environmental fragility analysis.

MATERIAL AND METHODS

The Urutu watershed (UW), located in the municipality of Aparecida do Taboado, east of Mato Grosso do Sul, is a critical eucalyptus/cellulose-producing region in Brazil. The UW has an approximate area of 99.45 km², between the parallels of 20°02'26” S and 20°10'22” S and the meridians of 51° 36'86”W and 51°27'24” W (Figure 1).

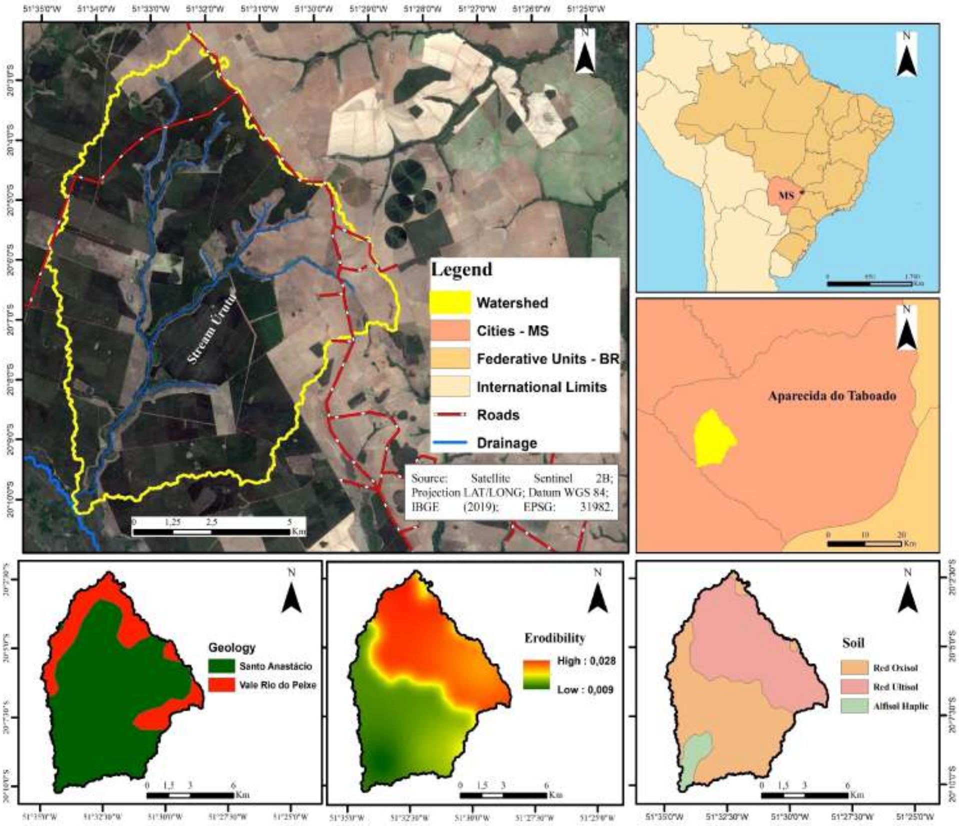

Figure 1 - Location of UW in the municipality of Aparecida do Taboado - MS. Source: Geology (SISLA, 2022); Soil (MATO GROSSO DO SUL, 1989); Erodibility (LIMA et al., 2021).

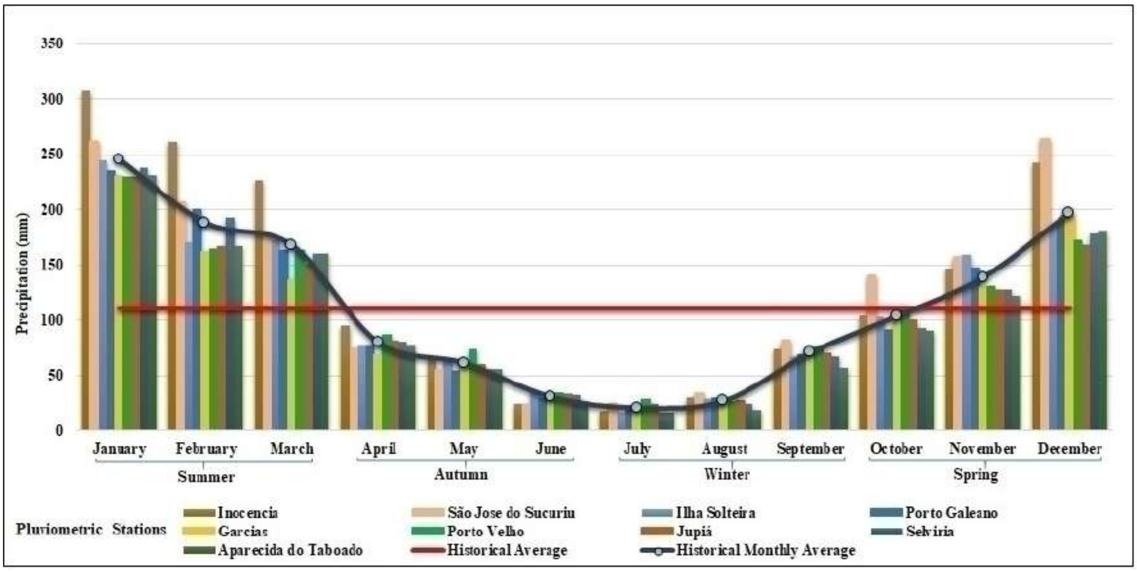

Figure 2 – Average monthly precipitation of the pluviometric stations near Aparecida do Taboado-MS. Source: coordinates of rainfall stations: Inocência: 51°55'52.292"W and 19°44'3.04"S; São José do Sucuriu: 52°13'25.215"W and 19°57'30.821"S; Ilha Solteira: 51°20'56.637"W and 20°25'21.516"S; Porto Galeano: 52°9'51.699"W and 20°5'40.723"S; Garcia: 52°13'13.288"W and 20°35'58.628"S; Porto Velho: 52°23'28.818"W and 20°48'3.037"S; Jupiá: 51°37'48.578"W and 20°47'57.944"S; Selviria: 51°25'41.401"W and 20°21'34.324"S; Aparecida do Taboado: 51°6'9.564"W and 20°3'54.077"S.

The UW is based on the lithologies of the Bauru Group, including the Santo Anastácio Formation, occupying an area of 23.06%, and the Caiuá Group, with the Vale, do Rio do Peixe Formation, with an area of 76.94%, both deposited on basalts from the Serra Geral Formation (Fernandes and Coimbra, 2000). The areas of soil present in the basin are 48.79% of Red Oxisol (LV), 46.15% of Red Ultisol (PV), and 5.05% of Alfisol Haplic (SX).

The climate in the region of Aparecida do Taboado is classified as Aw (ALVARES et al., 2013) and has characteristics of a tropical climate with a dry season in the winter. It has a rainfall regime characterized by a historical average annual rainfall of 1.332,6 mm between 1983 and 2016 (Figs. 2 and 3), according to data from the rainfall stations of the Agência Nacional Águas e Saneamento Básico (ANA) (ANA, 2019) and the Canal CLIMA of UNESP Ilha Solteira (CANAL CLIMA, 2019).

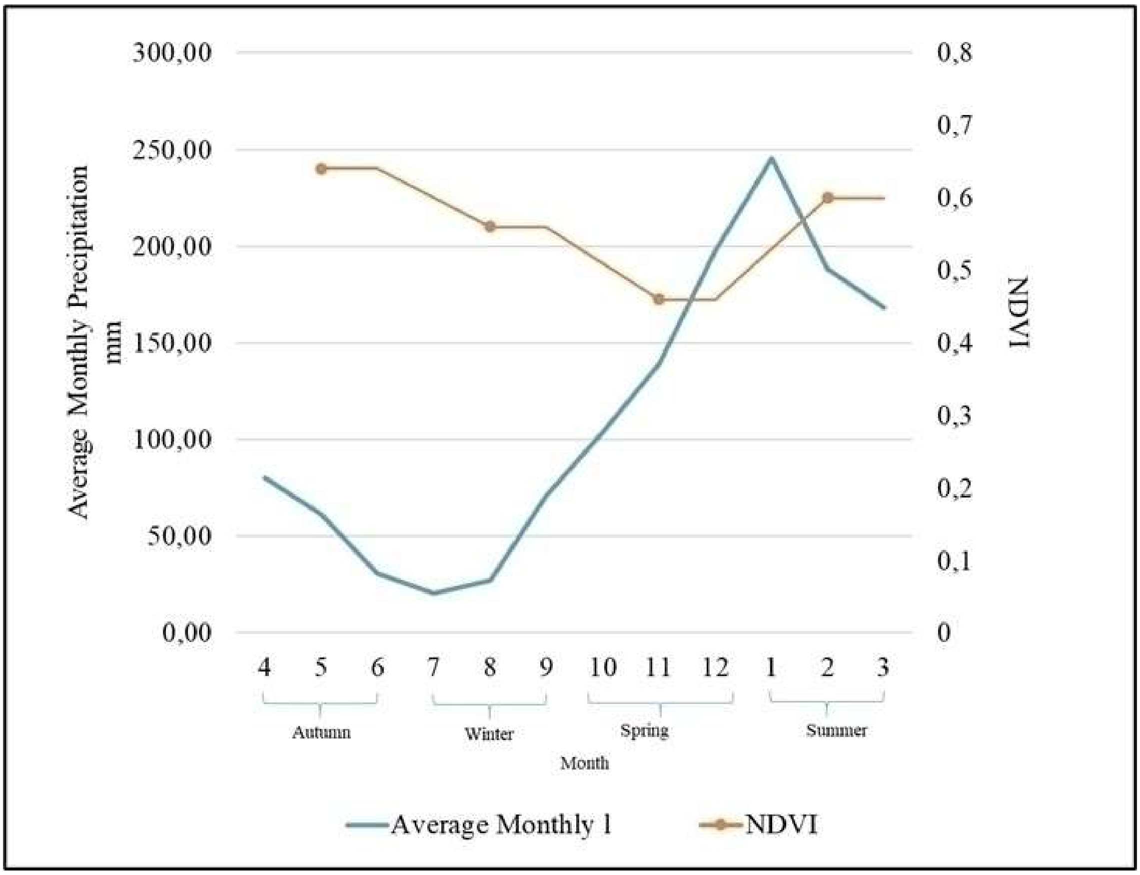

Figure 3 - Distribution of monthly average precipitation and average Normalized Difference Vegetation Index (NDVI). Source: Monthly average of nine rainfall stations close to UW; NDVI: seasonal mean value of the median of Sentinel 2B satellite images.

METHODOLOGY

The methodological procedures adopted were based on the proposed classification of surface freshwater quality governed by CONAMA Resolution 357/2005 (BRASIL, 2005) and CECA Deliberation 36/2012, evaluated by season: autumn 2019, winter 2019, spring 2019, and summer 2020. The steps taken can be verified according to the scheme shown in the flowchart below (Figure 4).

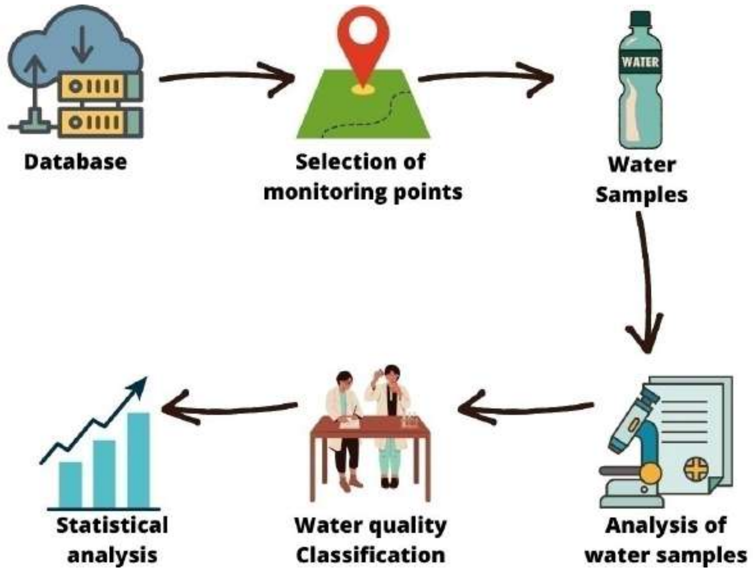

Figure 4 - Methodological flowchart.

The criteria for selecting water quality monitoring points were river confluences, land use patterns, land cover types, accessibility, and other considerations. Five monitoring points were selected (Figure 5 and Table 1).

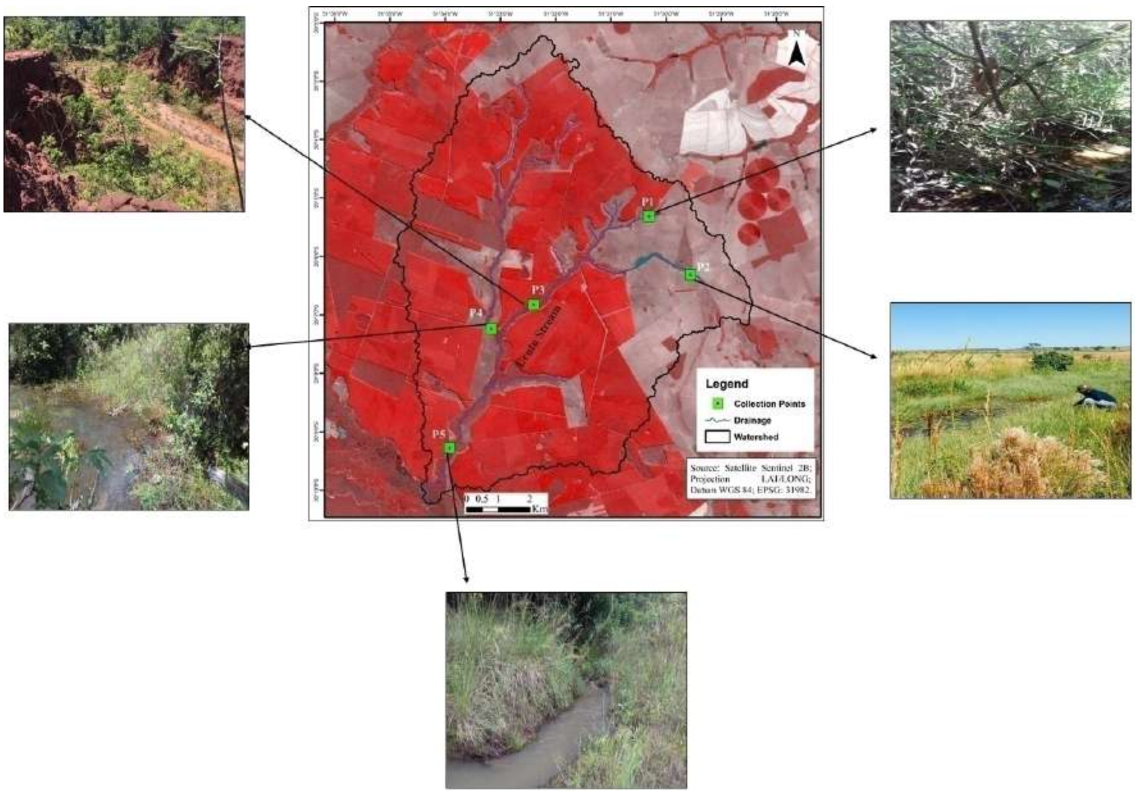

Figure 5 – UW water collection points.

Collection points	Coordinates	Land use and land cover (occupied area in %)
1	51°30'19,662"W 20°5'22,376"S	74 of pasture; 22.12 forestry; 2.67 riparian vegetation; 1 water.
2	51°29'32,939"W 20°6'21,841"S	97.32 pasture; 2.68 riparian vegetation.
3	51°32'25,267"W 20°6'52,181"S	47.6 pasture; 43.03 forestry; 7.62 riparian vegetation; 1.49 exposed soil.
4	51°33'12,596"W 20°7'16,452"S	16.98 pasture; 61.39 forestry; 9.71 riparian vegetation; 10.42 closed; 1.50 exposed soil.
5	51°33'55,678"W 20°9'16,596"S	18.24% pasture; 70.59 forestry; 7.71 riparian vegetation; 1.38 closed; 2.07 exposed soil.

Table 1 - Surface water monitoring points.

The water quality parameters are based on CONAMA Resolution 357/2005, CECA Deliberation 36/2012, and Resolution 52/2018 CERH/MS, which identifies water bodies, establishing five quality classes/frameworks.

Water collected in the field (simple samples) was carried out between 9 am and 1 pm, collected in 1-liter threaded amber bottles, previously sterilized and prepared with preservatives, and stored in a refrigerated isothermal box at a depth of 20 cm. The collection interval was three months, taking place in May 2019, August 2019, November 2019, and February 2020, accounting for four collections comprising the seasons. The samples were collected and packaged according to the recommendations of the Guia Nacional de Coleta e Preservação de Amostras (CETESB, 2011) and processed following the Standard Methods for the Examination of Water and Wastewater standards (APHA, 2005). The parameters are shown in Table 2, containing the equipment and analysis methods applied to the water samples.

Parameter	Unit	Equipment	Method
Temperature	°C	Thermometer (Horiba 50)	electrometric
pH		pH phmetro meter (Mettler Toleto)	potentiometric
Dissolved Oxygen (DO)	mg/L	Multiparameter Meter (Horiba 50)	spectrophotometric
Electric Conductivity (EC)	µs/cm^{-1}	Multiparameter Meter (Horiba 50)	amperometric
Total Alkalinity (ALK)	mg CaCO3 L^{-1}	Titrine (Metrohm)	titration
Organic Matter (OM)	mg/L	Titrine (Metrohm)	titration
Chloride (Cl^-)	mg/L	Liquid Chromatograph (Metronhm)	chromatography
Sulfate (SO_4^{-2})	mg/L	Liquid Chromatograph (Metronhm)	chromatography
Total Iron (Total Fe)	mg/L	DR 3900	spectrophotometric
Color	Pt/Co	DR 3900	spectrophotometric
Turbidity (NTU)	NTU	Turbidimeter (Horiba 50)	spectrophotometric
Total Dissolved Solids (TDS)	mg/L	Multiparameter Meter (Mettler Toleto)	gravimetric
Total Suspended Solids (TSS)	mg/L	Filtration Kit	gravimetric
Chemical Oxygen Demand (COD)	mg/L	DR 3900	spectrophotometric
Total Phosphorus (TP)	mg/L	DR 3900	spectrophotometric
Hardness	mg/L	DR 3900	spectrophotometric
Aluminum (Al)	mg/L	Atomic Absorption (Perkin Elmer)	spectrophotometric
Manganese (Mn)	mg/L	Atomic Absorption (Perkin Elmer)	spectrophotometric
Magnesium (Mg)	mg/L	Atomic Absorption (Perkin Elmer)	spectrophotometric
Sodium (Na)	mg/L	Flame Photometer	spectroscopy
Calcium (Ca)	mg/L	Atomic Absorption (Perkin Elmer)	spectrophotometric
Copper (Cu)	mg/L	Atomic Absorption (Perkin Elmer)	spectrophotometric
Dissolved Iron (Fe)	mg/L	Atomic Absorption (Perkin Elmer)	spectrophotometric

Table 2 - Equipment and methods for analyzing surface water quality parameters.

Next, the average classification was performed by UW parameter, in which the sum of classes (Special (0), Class I (1), Class II (2), Class III (3), Class IV (4)) participated by the variable divided by the number of collection points. A general classification of water quality for the basin was also applied based on the sum of the average classes divided by the number of sample points. After the classification, a Pearson's correlation statistical test was used to assist in interpreting the parameters monitored by Excel and the analysis of principal components - PCA by RStudio.

RESULTS AND DISCUSSION

MONITORING OF SURFACE WATER QUALITY IN AUTUMN 2019

In autumn, the general classification for this season was in class I (Table 3), which precedes the dry period and is characterized by the beginning of a decrease in the volume of precipitation, also presenting the highest vegetative index and better water quality among all seasons. (Figure 3). These results corroborate what was observed in other studies that found improved water quality related to vegetation cover (WANG et al., 2014; DING et al., 2015; ZHANG et al., 2018).

Parameters analyzed		Unit of measure	Monitoring Points					Classification by parameter
			1	2	3	4	5	
Physical Parameters	Temperature	°C	23	23	23	23	23	
	Color	Pt/Co	41	78	266	52	79	II
	Turbidity	NTU	1.49	5.99	30.5	4.48	8.9	S
	TDS	mg/L	6.16	21.8	6.84	8.06	9.1	I
	TSS	mg/L	3	8	101	1	7	
Chemical Parameters	pH		7.05	6.7	6.12	6.38	6.76	I
	DO	mg/L	10.5	7.44	6.28	8.62	11.93	I
	EC	µS/cm	12.54	44	14.41	19.56	18.69	S
	ALK	Ppm	8.2	19.2	7	9.8	9.6	
	OM	Ppm	0.88	2.16	24	1.68	1.04	
	Cl^-	Ppm	0.43	1.508	0.253	0.256	0	I
	SO_4^{-2}	Ppm	0	0	0	0	0	S
	Total Fe	Ppm	0.222	0.0111	0.215	0.387	0.305	
	COD	mg/L	25.96	31.18	12.56	0.79	7.54	
	TP	Ppm	0.01	0.01	0.02	0.01	0.01	I
	Hardness	Ppm	12	14	9	5	8	
	Al	Ppm	0.05	0	0.23	0	0	I
	Mn	Ppm	0	0.39	0	0	0	I
	Mg	Ppm	0.79	2.55	0.88	0.95	1.01	
	Na	Ppm	0	1	0	0	0	
	Ca	Ppm	2.96	4.91	3.4	2.91	2.98	
	Cu	Ppm	0.04	0.05	0.04	0.05	0.04	
	Fe	Ppm	0.57	0.13	0.85	0.43	0.35	III
Average rating per point			I	I	I	I	I	Autumn Overall Ranking I

Table 3 - Analytical results of surface water's physical and chemical parameters and their classification according to Resolution 357/2005 CONAMA at UW in autumn 2019.

The turbidity presented classification in all points and in general in the Special class (0 to 20). A positive correlation trend was observed in the correlation matrix, TSS, TDS, and OM. At point 3, turbidity and TSS showed concentrations that may be related to the topographic factor, as it is an aggradation area characterized by sediment deposition and an increase in organic and inorganic matter in the water (CHEN and CHAU, 2016). Turbidity is closely associated with rain (SILVA, 2013) and TSS, as the main factor responsible for turbidity is TSS (GILVEAR and PETTS, 1985; GRAYSON et al., 1996; HANNOUCHE et al., 2011).

The TDS was within the limits of class I (200 to 300) at all sampling points. The correlation matrix showed a positive correlation trend with EC, corroborating what Atekwana et al. (2004) found, and with conductive ions such as Ca, Cl-, and ALK (Table 4).

The color presented a classification in class II (menor que75) at points 2, 3, and 5 and class I at points 1 and 4. This parameter shows a positive correlation with TSS, OM, which was observed by Macedo (2004), and turbidity, as well as dissolved substances (ROCHA and COSTA, 2015), such as iron, Al, and TP.

The pH and the DO presented a general classification in class I. The stability of these parameters is associated with the high levels of vegetal biomass, protecting the soil and water resources, and decreasing precipitation

	DO	pH	EC	ALK	OM	Cl	Fe total	Cor	Turbidity	TDS	TSS	COD	TP	Hardness	Al	Mg	Ca	Cu
pH	0.70																	
EC	-0.36	0.09																
ALK	-0.27	0.22	0.99															
OM	-0.64	-0.77	-0.28	-0.39														
Cl	-0.48	0.19	0.90	0.91	-0.19													
Fe total	0.43	-0.20	-0.74	-0.74	-0.08	-0.88												
Color	-0.60	-0.76	-0.21	-0.33	0.99	-0.17	-0.12											
Turbidity	-0.55	-0.78	-0.25	-0.37	0.97	-0.24	-0.05	0.99										
TDS	-0.33	0.13	0.99	0.99	-0.27	0.91	-0.79	-0.19	-0.23									
TSS	-0.60	-0.74	-0.28	-0.39	1.00	-0.19	-0.10	0.99	0.98	-0.26								
COD	-0.18	0.53	0.51	0.57	-0.12	0.78	-0.90	-0.12	-0.21	0.58	-0.10							
TP	-0.61	-0.75	-0.33	-0.43	1,00	-0.22	-0.05	0.98	0.97	-0.31	1.00	-0.13						
Hardness	-0.16	0.51	0.53	0.58	-0.09	0.77	-0.92	-0.06	-0.14	0.60	-0.06	0.99	-0.10					
Al	-0.54	-0.62	-0.43	-0.51	0.97	-0.24	-0.06	0.93	0.91	-0.40	0.97	-0.04	0.98	-0.01				
Mg	-0.38	0.12	0.99	0.98	-0.23	0.93	-0.82	-0.16	-0.20	1.00	-0.22	0.61	-0.27	0.64	-0.35			
Ca	-0.55	-0.01	0.93	0.90	0.02	0.94	-0.91	0.08	0.02	0.94	0.02	0.69	-0.02	0.71	-0.09	0.96		
Cu	-0.42	-0.16	0.71	0.70	-0.36	0.61	-0.19	-0.38	-0.40	0.64	-0.41	0.03	-0.41	-0.03	-0.51	0.63	0.51	
Fe	-0.23	-0.47	-0.79	-0.84	0.78	-0.59	0.35	0.70	0.70	-0.78	0.77	-0,28	0.80	-0.30	0.88	-0.74	-0.54	-0.64

Table 4 - Correlation matrix of physical and chemical parameters of surface water at UW in autumn 2019.

The EC classified in the Special class (menor que 50) showed a positive correlation trend with ALK, Cl, Mg, and Ca, which are parameters associated with EC. The highest occurrence of EC was detected at point 2 and may be related to livestock activities, combined with the elevation of dissolved ion concentration (ANJINHO et al., 2020).

PT, classified as class I (menor que 0.020), showed a trend of positive correlation with turbidity and, mainly, with OM and TSS (Table 4). The reduction in total P concentration may be related to the vegetation cover, as riparian vegetation contributes to reducing phosphorus input into the water body (NEILEN et al., 2017).

Al presented a value of menor que0.1 and was occasionally categorized in point 1 as class I. Between points 2, 4, and 5, the Special class (0) was identified, and in point 3, Class III (,enor que 0.2), with the same classification for Fe. Both parameters showed a positive correlation with color, turbidity, and TSS. Occasionally, points 1 and 3 have the highest concentrations of Fe, with a positive correlation trend, not only with color, turbidity, and TSS but also with OM and TDS, whose association of Fe with OM can increase the color (RICHTER and NETTO, 1991). This Fe concentration may also be associated with the basin's geology, as they are based on the Santo Anastácio Formation, which contains a thin layer of iron in its composition (IPT, 1981).

MONITORING OF SURFACE WATER QUALITY IN THE WINTER OF 2019

In winter, the general classification for this station was in class I. However, higher concentrations individually between some parameters are already presented in the other points, such as pH, Fe, and Al (Table 5).

Parameters analyzed		Unit of measure	Monitoring points					Classification by parameter
			1	2	3	4	5	
Physical Parameter	Temperature	°C	23	*	23	23	23	
	Color	Pt/Co	192	*	45	43	43	I
	Turbidity	NTU	21.4	*	7.36	3.19	5.66	S
	TDS	mg/L	9.49	*	11.19	8.8	11.29	I
	TSS	mg/L	3	*	2	0	4	
Chemical Parameters	pH		6.59	*	5.64	5.91	6.36	III
	DO	mg/L	9.62	*	10.5	10.54	10.43	S
	EC	µS/cm	18.97	*	22.4	17.6	22.6	S
	ALK	Ppm	11.1	*	12.1	11.2	10.1	
	OM	Ppm	2.88	*	2.24	1.44	0.72	
	Cl^-	Ppm	0.861	*	0.341	0	0	I
	SO_4^{-2}	Ppm	0.85	*	0.168	0.129	0.149	I
	Fe total	Ppm	0.616	*	0.657	0.417	0.473	
	COD	mg/L	11.75	*	6.33	0	0	
	TP	Ppm	0.03	*	0	0	0	I
	Hardness	Ppm	19	*	8	7	7	
	Al	Ppm	2.13	*	2.31	1.43	1.53	IV
	Mn	Ppm	0	*	0	0	0	
	Mg	Ppm	0.6	*	0.27	0.98	0.96	
	Na	Ppm	1	*	1	1	1	
	Ca	Ppm	2.18	*	2.19	1.95	2	
	Cu	Ppm	0	*	0	0	0	
	Fe	Ppm	1.62	*	4.36	0.52	0.57	III
Average rating per point			I	*	I	I	I	General Rating Winter I

Table 5 - Analytical results of physical and chemical parameters of surface waters and their classification according to Resolution 357/2005 CONAMA of UW in winter.

Turbidity was present in the Special class, mainly due to low precipitation, as in autumn. This also showed a positive correlation trend with SST (Table 6).

Color also presented a general classification in class I, except for point 1 in class II. There is a trend towards a positive correlation between this parameter and sulfate, as it is involved in the oxidation of organic matter (RIBEIRO et al., 2016), since in the process of degradation of organic matter, there is a release of humic and phenolic acids responsible for increasing the color (RICHTER and NETTO, 1991).

The TDS was identified as class I for all points, showing a positive correlation trend with EC (Table 6) due to the lower water input from precipitation in the system

	DO	pH	EC	ALK	OM	Cl^-	SO_4^{-2}	Total Fe	Color	Turbidity	TDS	TSS	COD	TP	Hardness	Al	Mg	Ca
pH	-0.77																	
EC	0.30	-0.16																
ALK	0.09	-0.70	-0.08															
OM	-0.71	0.09	-0.29	0.64														
Cl^-	-0.91	0.45	-0.18	0.31	0.92													
SO_4^{-2}	-1.00	0.71	-0.34	0.00	0.77	0.93												
Total Fe	-0.44	-0.07	0.38	0.61	0.78	0.75	0.48											
Color	-0.99	0.72	-0.37	-001	0.76	0.92	1.00	0.45										
Turbidity	-0.98	0.67	-0.20	0.05	0.79	0.97	0.99	0.60	0.98									
TDS	0.30	-0.16	1.00	-0.08	-0.29	-0.17	-0.34	0.38	-0.37	-0.19								
TSS	-0.39	0.62	0.67	-0.53	-0.08	0.27	0.31	0.32	0.29	0.40	0.67							
COD	-0.84	0.33	-0.09	0.42	0.94	0.99	0.87	0.83	0.86	0.92	-0.09	0.25						
TP	-0.99	0.72	-0.38	-0.02	0.75	0.92	1.00	0.44	1.00	0.98	-0.38	0.29	0.85					
Hardness	-0.99	0.68	-0.34	0.05	0.80	0.95	1.00	0.51	1.00	0.99	-0.34	0.29	0.89	1.00				
Al	-0.42	-0.14	0.30	0.69	0.82	0.75	0.47	0.99	0.44	0.58	0.31	0.22	0.84	0.43	0.50			
Mg	0.19	0.38	-0.37	-0.80	-0.71	-0.57	-0.24	-0.95	-0.22	-0.37	-0.37	-0.08	-0.69	-0.20	-0.28	-0.97		
Ca	-0.54	0.01	0.29	0.59	0.83	0.82	0.58	0.99	0.55	0.69	0.29	0.32	0.89	0.54	0.61	0.99	-0.92	
Fe	0.07	-0.58	0.46	0.83	0.54	0.34	-0.02	0.85	-0.04	0.12	0.46	-0.01	0.48	-0.05	0.03	0.87	-0.97	0.79

Table 6 - Correlation matrix of physical and chemical parameters of surface water at UW in the winter of 2019.

The pH specifically presented a classification difference: point 1, located upstream, and point 5, close to the mouth, which was classified in class I; points 3 and 4 have a slightly acidic pH, categorized in class IV, which can be explained by the decomposition of the accumulation of leaves, vegetation branches, organic matter, resulting in the release of humic acid (ANJINHO et al., 2020) from the parts highest on the terrain (headwaters). It should be noted that point 3 is in a sediment deposition area; therefore, TSS tends to accumulate in this dry period, increasing concentration and decreasing transport (Stevaux and Latrubresse, 2017), which corroborates with what is indicated in the correlation matrix, which showed a trend of positive correlation with the TSS, turbidity, color and SO42.

The OD was generally in class I (>6 menor que 10), and point 1 was the only one at this station classified in class I due to a slight variation in the concentration value, in which the other points were within the limits of the particular class (>10).

As in autumn, EC in winter remained in the Special class. In this season, there was also a trend towards a positive correlation between EC and TDS due to the lower precipitation rate, limiting the entry of material through the runoff.

The Cl- was present in class I (menor que 250) in points 1 and 3 and was absent in points 4 and 5. SO4-2 and Cl were present in class I, differently from autumn, where their occurrence was not identified. Both parameters tend to correlate positively with OM due to the dissolution of these elements in substances that compose these parameters.

Fe predominated in class III (menor que 5.0), with the highest concentrations in points 1 and 3, which, as in the previous season, showed a positive correlation with OM and TDS.

Al showed higher concentrations at all points, classified in class IV (>0.2), and similar to Fe, this element also showed a positive correlation with OM.

MONITORING OF SURFACE WATER QUALITY MONITORING IN SPRING 2019

Parameters analyzed		Unit of measure	Monitoring points					Classification by parameter
			1	2	3	4	5	
Physical Parameters	Temperature	°C	20	*	20	20	20	
	Color	Pt/Co	579	*	637	99	71	II
	Turbidity	NTU	49.4	*	85.7	4.94	7.95	I
	TDS	mg/L	11.76	*	4.67	7.29	9.53	I
	TSS	mg/L	13	*	0	0	1	
Chemical Parameters	pH		7.08	*	5.53	6.13	6.62	II
	DO	mg/L	8.78	*	8.52	9.5	10.62	I
	EC	µS/cm	23.5	*	9.53	14.58	19.06	S
	ALK	Ppm	8.6	*	5.9	9.1	9.9	
	OM	Ppm	4.64	*	4.48	0	0	
	Cl^-	Ppm	2.152	*	0.472	0	0	I
	SO_4^{-2}	Ppm	0.301	*	0.897	0.202	0.127	I
	Total Fe	Ppm	4.85	*	1.574	1.706	0.739	
	COD	mg/L	74.28	*	9.92	21.06	0	
	TP	Ppm	0.07	*	0.06	0	0	I
	Hardness	Ppm	1	*	3	26	8	
	Al	Ppm	4.34	*	11.08	0.58	0.82	IV
	Mn	Ppm	0	*	0	0	0	-
	Mg	Ppm	0.75	*	0.75	0.78	1.06	
	Na	Ppm	1	*	1	0	0	
	Ca	Ppm	3.16	*	2.4	3.26	4.03	
	Cu	Ppm	0.03	*	0.13	0.03	0.03	
	Fe	Ppm	4.25	*	1.83	1.5	1.21	III
Average rating per point			II		II	I	I	Spring Overall Ranking II

Table 7 - Analytical results of physical and chemical parameters of surface waters and their classification according to Resolution 357/2005 CONAMA of UW in Spring.

In spring, it was found that point 2 was still dry, resulting from the removal of riparian vegetation. In the basin region, spring is characterized by the beginning of the rainy season, with a significant accumulation of litter from the vegetation due to previous seasons (INKOTTE et al., 2022). According to data analysis, all parameters generally increased their indices (Table 7). The turbidity showed variations in the concentration between the sampling points, as well as in other works (ANTUNES et al., 2014; ROSSITER et al., 2015; AMORIM et al., 2017), with points 1 and 3 in class II (40 to 70) and points 4 and 5 in the particular class.

Color proved to be general in class 2 (>75), and occasionally, except for point 4 in class I, the others were classified in class II. It can be observed that there was an increase in the concentration of this parameter in previous seasons, mainly due to the increase in the concentration of dissolved substances such as sulfate, Fe, and even OM, registering a trend of positive correlation between these elements (Table 8).

	OD	pH	EC	AKL	OM	Cl^-	SO_4^{-2}	Total Fe	Color	Turbidity	TDS	TSS	COD	TP	Hardness	Al	Mg	Ca	Cu
pH	0.31																		
EC	0.28	1.00																	
ALK	0.81	0.71	0.68																
OM	-0.86	-0.04	-0.01	-0.73															
Cl^-	-0.57	0.59	0.62	-0.13	0.76														
SO_4^{-2}	-0.74	-0.73	-0.71	-0.99	0.70	0.06													
Total Fe	-0.57	0.60	0.62	-0.05	0.65	0.97	-0.04												
Color	-0.89	-0.15	-0.12	-0.80	0.99	0.69	0.77	0.58											
Turbidity	-0.83	-0.41	-0.39	-0.93	0.91	0.42	0.92	0.29	0.95										
TDS	0.29	1.00	1.00	0.69	-0.01	0.61	-0.71	0.62	-0.12	-0.39									
TSS	-0.35	0.78	0.80	0.13	0.57	0.97	-0.20	0.95	0.48	0.18	0.80								
COD	-0.51	0.64	0.66	0.04	0.57	0.94	-0.13	0.99	0.50	0.19	0.66	0.95							
TP	-0.85	0.04	0.07	-0.68	1.00	0.81	0.64	0.71	0.98	0.87	0.07	0.63	0.63						
Hardness	0.34	-0.22	-0.24	0.40	-0.76	-0.61	-0.44	-0.40	-0.73	-0.69	-0.23	-0.52	-0.31	-0.76					
Al	-0.77	-0.58	-0.55	-0.97	0.81	0.24	0.98	0.11	0.87	0.98	-0.56	-0.02	0.00	0.76	-0.60				
Mg	0.93	0.27	0.25	0.63	-0.65	-0.48	-0.53	-0.58	-0.68	-0.58	0.25	-0.31	-0.56	-0.65	0.01	-0.52			
Ca	0.93	0.63	0.61	0.95	-0.74	-0.24	-0.90	-0.23	-0.80	-0.86	0.61	0.01	-0.17	-0.69	0.23	-0.87	0.85		
Cu	-0.59	-0.81	-0.79	-0.95	0.56	-0.12	0.98	-0.24	0.64	0.85	-0.80	-0.37	-0.33	0.49	-0.38	0.94	-0.38	-0.81	
Fe	-0.57	0.61	0.63	-0.09	0.72	0.99	0.01	0.99	0.64	0.37	0.62	0.97	0.97	0.77	-0.53	0.18	-0.52	-0.23	-0.18

Table 8- Correlation matrix of physical and chemical parameters of surface water at UW in spring 2019.

The pH predominated in class II; point 6 was presented in class IV, and the others in class I. This may be related to the physical characteristics of point 3. This parameter showed a positive correlation with EC and TDS, TSS, total Fe, and Fe (Table 8), a correlation already observed in some parameters in previous seasons.

The DO at points 1, 3, and 4 was presented in class I, and point 5 in the Special class. It was observed that there was a decrease in the concentration of this parameter in previous seasons. This may be related to the increase in TSS concentration in the surface water temperature absorbed by solids (KANNEL et al., 2007; NAVEEDULLAH et al., 2016) by OM, COD, and Fe, resulting in DO consumption so much so that the correlation matrix (Table 8) showed that the DO has a negative correlation tendency with the TSS, the OM, Fe, and COD.

The EC remained in the Special class, as in previous seasons, and also showed a very high positive correlation trend for pH and TDS and a high for ALK, Fe, Cl, TSS, and Ca parameters. This can be explained by entering materials into the water body due to increased precipitation and, consequently, the release of Fe and Ca ions, which tended to show a positive correlation.

The Cl- was another parameter that remained in the same class as autumn and was not detected at points 4 and 5. SO4-2, as well as Cl-, which remained in class I (menor que 250), compared to the previous season.

TP specifically presented only in point 1 with class II (menor que 0.030) and in point 3 with classification in class III (menor que 0.05). This also showed a high positive correlation trend with OM, which may be associated with anthropic or natural actions (VON SPERLING and CHERNICHARO, 2002; OLIVEIRA et al., 2017). The concentration of this element may also be associated with the accumulation of organic matter from plant material (ANDRADE et al., 2008), dissociation of suspended sediments, and soil leaching by precipitation (MARINS et al., 2007; SANTOS et al., 2010).

The Fe presented a general classification in class III (menor que 5.0), with a positive correlation trend between the color, turbidity, COD, TDS, and TSS parameters, which already presented this correlation characteristic in previous seasons.

The Al remained in class IV (>0.2), increasing its concentration: in point 4, which doubled the concentration, and in point 3, where it was tripled. On the other hand, points 4 and 5 showed a drop in concentration and were identified in class III, showing once more a trend of positive correlation with SO4-2, OM, color, turbidity, and TP.

MONITORING OF SURFACE WATER QUALITY IN THE SUMMER OF 2020

This season is characterized by an increase in precipitation, with an average value of 200 mm and in the volume of plant density and temperature, providing the acceleration of litter decomposition processes. The general classification registered in the summer was in class III (Table 9), quite different from what was observed in the other seasons.

Parameters analyzed		Unit of measure	Monitoring points					Classification by parameter
			1	2	3	4	5	
Physical Parameter	Temperature	°C	19.6	20	19.8	19.8	19.7	
	Color	Pt/Co	712	332	412	178	284	II
	Turbidity	NTU	35.4	19.1	27.3	12.4	25.4	I
	TDS	mg/L	19.75	24.7	12.65	10.75	11.15	I
	TSS	mg/L	45	16	0	0	1	
Chemical Parameters	pH		5.85	6.29	5.86	6.14	6.3	II
	DO	mg/L	10.26	10.3	10.58	9.97	9.93	I
	EC	µS/cm	39.5	49.4	25.3	21.5	22.3	S
	AKL	Ppm	20.7	26.5	11.2	10.4	12.1	
	OM	Ppm	6.08	8.56	6.82	6.8	5.28	
	Cl^-	Ppm	0.321	0.239	0.218	0	0.089	I
	SO_4^{-2}	Ppm	0.278	0.124	0.123	0.18	0.08	I
	Total Fe	Ppm	5.278	5.774	11.655	2.905	5.122	
	COD	mg/L	25.47	35.88	45.96	216.65	26.59	
	TP	Ppm	0	0.004	0.003	0	0.001	I
	Hardness	Ppm	5	18	0	12	17	
	Al	Ppm	0.18	0	0.18	0.04	0.47	II
	Mn	Ppm	0	0	0	0	0	-
	Mg	Ppm	1.53	2.43	0.68	0.95	0.93	
	Na	Ppm	1	1	1	1	1	
	Ca	Ppm	1.48	2.72	1.51	1.74	1.61	
	Cu	Ppm	0.04	0.05	0.05	0.05	0.06	
	Fe	Ppm	20.6	8.19	0.05	2.75	4.68	III
Average rating per point			II	I	I	I	I	Overall Summer Ranking I

Table 9 - Analytical results of surface water's physical and chemical parameters and their classification according to UW Resolution 357/2005 CONAMA in the summer.

Turbidity concentrations in the summer at points 2 and 4 were in a Special class, and points 1, 3, and 5 were in class I. In general, with class I, there was a trend of positive correlation with TSS and Fe (Table 10). It is important to note that in this season, there were changes in land use and land cover, namely the forestry harvest near points 1 and 3, which did not show significant changes such as increased concentration of TSS and OM and may increase its concentration in the rainy season, as already observed in other works (Anjinho et al., 2020). It can be observed that changes in land use and land cover, such as harvesting activity, are related to the increase in the concentration of solids in the water (ENSIGN and MALLIN, 2001; LIMA and ZAKIA, 2006).

The TDS was presented in all points in class I due to the higher vegetation density in the summer. It also showed a positive correlation trend with EC, Cl-, ALK, Fe, and Ca (Table 10). The highest TDS values were detected in areas containing pasture, such as points 1 and 2, where increased TDS concentration can unbalance biochemical reactions (WANG et al., 2013).

The color showed varied concentrations at the collection points; the highest was in the summer. This is due to the increase in precipitation, which caused an increase in dissolved substances and organic materials, with a record of a positive correlation trend between SO4-2, TSS, Fe, and Turbidity (Table 10).

	DO	pH	EC	ALK	OM	Cl^-	SO_4^{-2}	Total Fe	Color	Turbidity	TDS	TSS	COD	TP	Hardness	Al	Mg	Ca	Cu
pH	-0.63																		
EC	0.36	0.06																	
ALK	024	0.16	0.99																
OM	0.43	0.19	0.66	0.61															
Cl^-	0.70	-0.52	0.73	0.68	0.22														
SO_4^{-2}	0.08	-0.63	0.28	0.26	-0.08	0.43													
Total Fe	0.87	-0.52	-0.04	-0.13	0.10	0.44	-028												
Color	0.46	-0.71	0.45	0.42	-0.18	0.88	0.70	0.25											
Turbidity	0.40	-0.62	0.20	0.19	-0.45	0.77	0.40	0.41	0.90										
TDS	0.36	0.06	1.00	0.99	0.66	0.73	0.28	-0.04	0.45	0.20									
TSS	0.17	-0.42	0.66	0.66	0.00	0.77	0.81	-0.18	0.88	0.65	0.66								
COD	-0.42	0.10	-0.46	-0.47	0.09	-0.75	0.13	-0.48	-0.59	-0.76	-0.46	-0.41							
TP	0.62	0.21	0.48	0.43	0.72	0.34	-0.56	0.59	-0.15	-0.12	0.48	-0.24	-0.42						
Hardness	-0.69	0.97	0.21	0.32	0.19	-0.40	-0.43	-0.66	-0.55	-0.53	0.21	-0.19	0.07	0.10					
Al	-0.74	0.22	-0.87	-0.80	-0.79	-0.77	-0.20	-0.38	-0.42	-0.19	-0.87	-0.45	0.41	-0.70	0.15				
Mg	0.10	0.35	0.95	0.97	0.70	0.48	0.15	-0.27	0.19	-0.06	0.95	0.51	-0.30	0.44	0.49	-0.73			
Ca	0.05	0.62	0.71	0.72	0.85	0.10	-0.29	-0.19	-0.31	-0.48	0.71	-0.02	-0.06	0.67	0.65	-0.61	0.85		
Cu	-0.44	0.72	-0.49	-0.43	-0.23	-0.64	-0.92	-0.02	-0.75	-0.41	-0.49	-0.80	0.00	0.19	0.55	0.54	-0.30	0.09	
Fe	-0.01	-0.30	0.60	0.62	-0.11	0.66	0.78	-0.33	0.82	0.62	060	0.98	-0.38	-0.35	-0.06	-0.31	0.49	-003	-0.70

Table 10 - Correlation matrix of physical and chemical parameters of surface water at UW in the summer of 2020.

The pH showed a slightly elevated acidity level in class IV for points 1 and 3 (Table 9). This is due to the influence of increased precipitation (DAMASCENO et al., 2015; ALVARENGA et al., 2016; BEN-ELEDO et al., 2017). The pH showed a tendency of negative correlation with the OM in such a way that when the decomposition processes accelerate, there is an increase in the pH (Table 10). Points 2, 4, and 5 were classified within the limit established for class I (Table 9). It should be noted that although points 1 and 3 have little in common regarding land use and land cover, both showed the most altered parameters among all the analyzed stations, especially point 3.

The DO at points 1, 2, and 3 with the Special class and points 4 and 5 with class I (Table 9) indicated that there was greater water oxygenation at this station, and that may be related to the increase in water volume of precipitation (ZANATA et al., 2015; ARAÚJO et al., 2018).

The EC featured in the Special class at all points for this season. This parameter reached the highest values in this season, showing a positive correlation trend with TDS, TSS, ALK, EC, Mg, and Cl- (Table 10).

The ALK showed the highest values this season, focusing on points 1 and 2. It tended to have a positive correlation with TDS, TSS, TP, Cl-, Ca, and Mg (Table 10) due to increased precipitation and ion availability originating from the dissolution of rock and soils (LIMA and ZAKIA, 2006; CRUZ et al., 2016).

The Cl- and SO4-2 parameters at all points showed class I values. The sulfates detected in natural water resources are also ions that can come from the dissolution of soils and rocks (FERNANDES et al., 2012). Cl- tended to positively correlate with turbidity, TDS, and TSS, and SO4-2 with color, TSS, and Fe. The TP was in a special class at points 1 and 4 and points 2, 3, and 5 in class I. The TP showed a positive correlation with the OM (Table 10). P, nitrogen, and K are nutrients that may be related to increased water discharge and runoff over the forest exploitation area (MALMER and GRIP, 1994; VITAL et al., 1999). Al resulted in the Special class (0) at point 2, class I (menor que 0.1) at point 4, class II (>0.1) at points 1 and 3, and class III (menor que 0.2) at point 5. For summer, class II showed a very high positive correlation trend with OM, ALK, EC, and DO.

Total Fe (dissolved more in suspension) showed high concentrations in this season, and Fe showed higher concentrations at points 1, 2, 4, and 5, overall with class III (menor que 5.0). This is due to natural conditions with the geological (IPT, 1981) and pedological formation of the basin as there is an occurrence of iron concentration in the other stations.

PCA ANALYSIS

In autumn, the first principal component (PC1) explained 50.50% of the total variance (Figure 6). Figure 7 showed that the sample from point 2 was positively and primarily affected by EC, ALK, CL-, and Mg parameters (Table 11). PC1 was also negatively affected by the chemical parameter Fe, closely related to samples from points 4 and 5. Therefore, this component measures the preponderance of SDT, ALK, CL-, and Mg over the other water quality parameters (Fe).

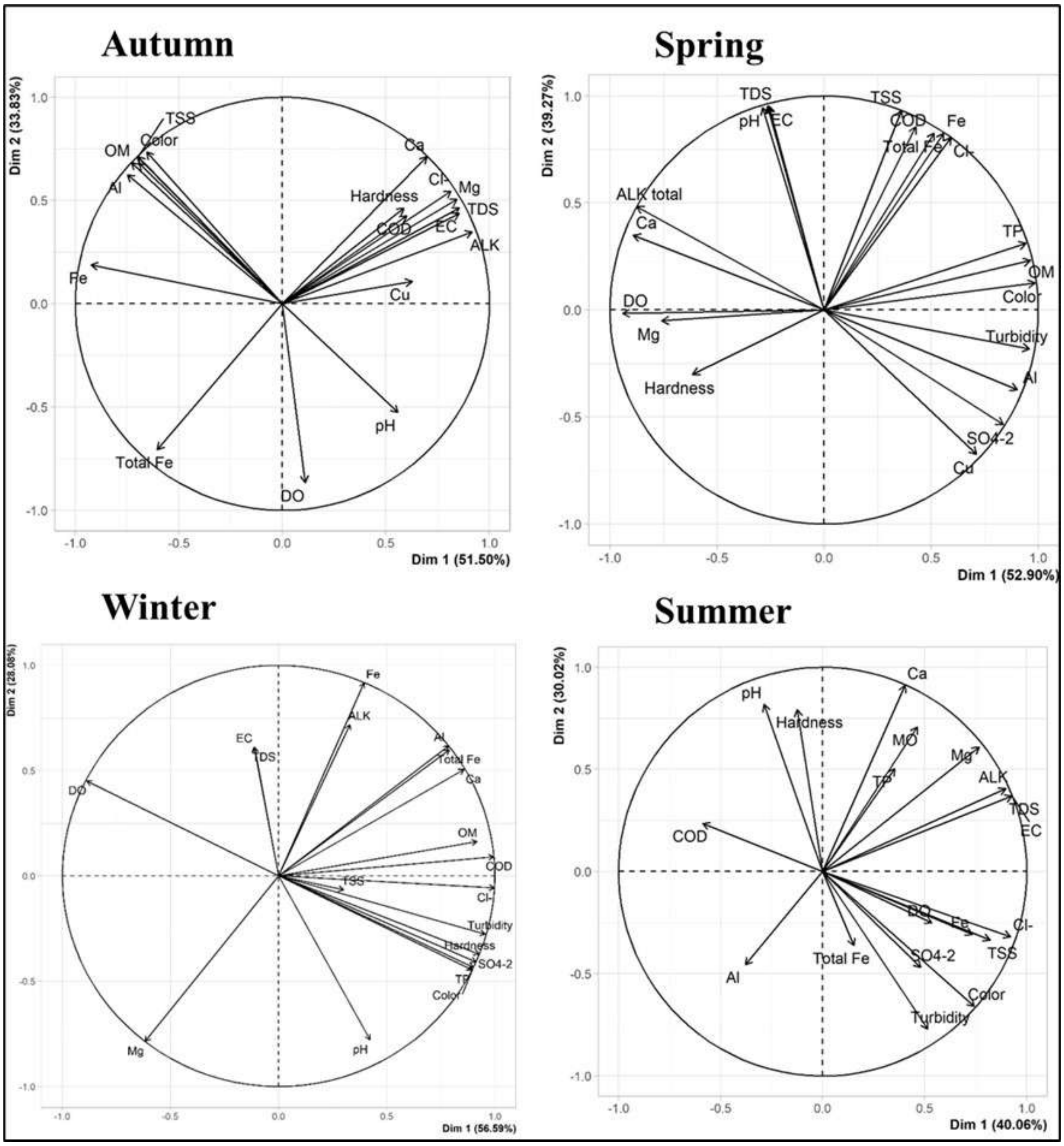

Figure 6 - Principal component analysis - PCA per season of water quality parameters.

The autumn's second principal component (PC2) explained 33.83% of the total variation in which the parameters (OM, Color, TSS, Turbidity, TP, Ca, and Al) were positive and vastly influential. It was also negatively and primarily affected by chemical parameters (DO). PC2 highlighted the importance of the parameters resulting from the erosive processes in point 3 and the agreement of these parameters with point 2, which may be specifically associated with the impacts of livestock activities in the area where the study was conducted. Similar component loading patterns were obtained for PC1 in winter, which explained 56.59% of the total variation. It was positively and largely influenced by parameters

OM, Cl-, SO4-2, Color, Turbidity, TP, Hardness, Ca, Al, and negatively by DO. With 28.08% of the total variance, PC2 was positively influenced by the parameters EC, Total Fe, TDS, Al, and Fe and negatively affected by pH.

Spring PC1, which explained 52.90% of the total variance, was negatively affected by DO and positively affected by OM, SO4-2, Color, Turbidity, TP, and Al (Figure 6 and Table 11). These results may confirm a seasonal variation of water quality parameters in this dynamic river system compared to quality parameters collected from autumn and winter. The second principal component of spring (PC2) explained 39.27% in which the EC, Cl-, Color, TDS, TSS, COD, and Fe parameters were positive and largely influential in the total variation.

Figure 6 and Table 11 indicate that summer PC1, with 40.067% of the total variance, was primarily affected by parameters EC, ALK, Cl-, Color, TDS, TSS, Mg, and Fe. Points 1, 2, and 3 explain most of the changes in water quality parameters during the summer. PC2 explained 30.02% of the total variation, as it was positively influenced by the parameters OM, pH, Mg, and Ca in the total variation and negatively by the parameters Color and Turbidity. PC2 highlighted the importance of the parameters resulting from the greater volume of apparent water from points 4 and 5 results of the water purification process.

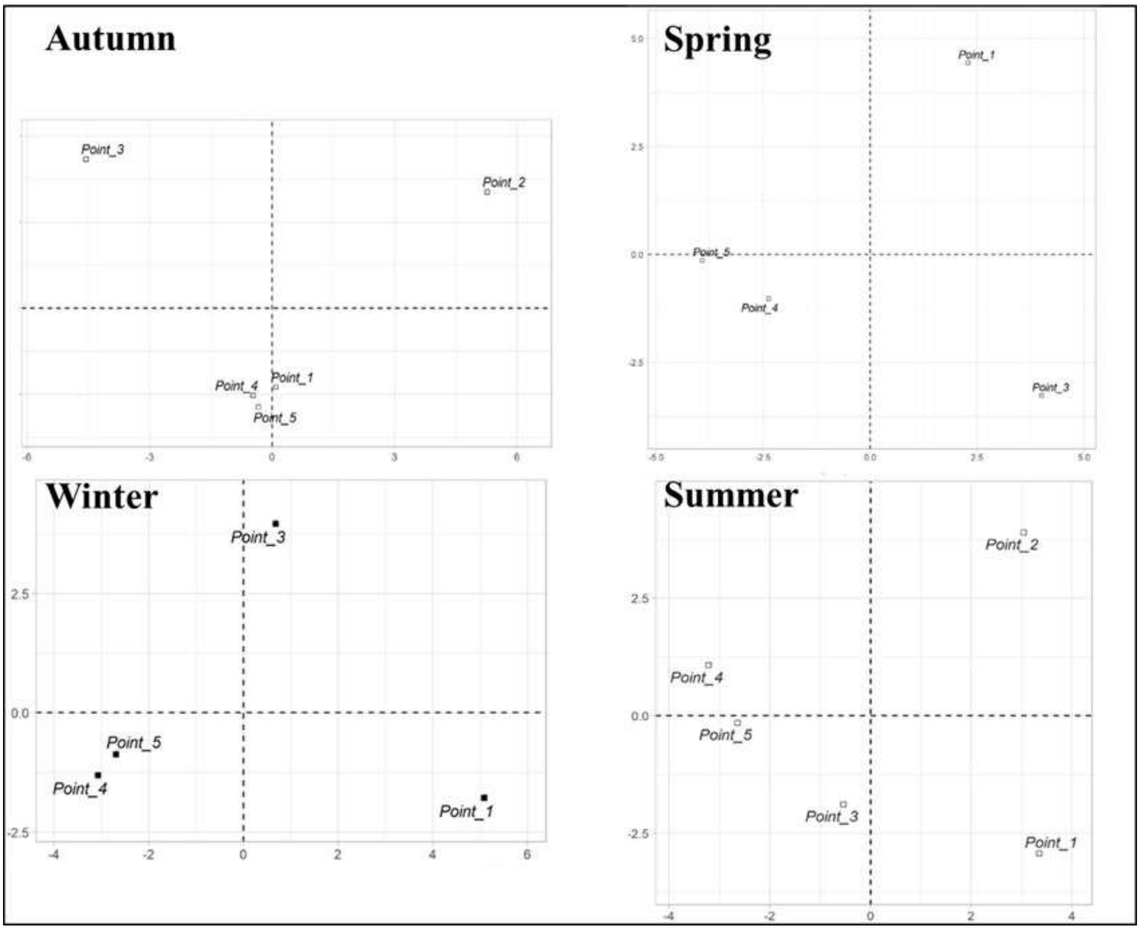

Figure 7- Pc’s score chart for water sample datasets.

	Autumn		Winter		Spring		Summer	
Variance (%)	51,50	33,83	56,59	28,08	52,90	39,27	40,06	30,02
	PC 1	PC 2	PC 1	PC 2	PC 1	PC 2	PC 1	PC 2
pH	0.18	-0.21	0.13	-0.34	-0.09	0.34	-0.11	**0.34**
DO	0.03	-0.34	-0.27	0.19	-0.29	-0.01	0.19	-0.10
EC	**0.27**	0.17	-0.03	**0.26**	-0.08	**0.34**	**0.33**	0.16
ALK	**0.29**	0.14	0.10	0.31	-0.27	0.17	**0.32**	0.17
OM	-0.22	**0.28**	**0.28**	0.07	**0.30**	0.08	0.17	**0.30**
Cl-	**0.26**	0.21	**0.30**	-0.02	0.18	**0.29**	**0.33**	-0.13
SO4-2	-	-	**0.28**	-0.18	**0.26**	-0.19	0.18	-0.19
Total Fe	-0.19	-0.28	0.24	**0.26**	0.16	**0.30**	0.06	-0.15
Color	-0.21	**0.29**	**0.27**	-0.19	**0.30**	0.05	**0.27**	-0.27
Turbidity	-0.22	**0.27**	**0.29**	-0.12	**0.29**	-0.06	0.19	-0.32
TDS	**0.27**	0.18	-0.03	**0.26**	-0.08	**0.34**	**0.33**	0.16
TSS	-0.22	**0.28**	0.09	-0.03	0.11	**0.33**	**0.30**	-0.14
COD	0.19	0.17	**0.30**	0.04	0.13	**0.31**	-0.21	0.10
TP	-0.23	**0.27**	**0.27**	-0.19	**0.29**	0.11	0.13	**0.21**
Hardness	0.19	0.18	**0.28**	-0.16	-0.19	-0.11	-0.05	0.33
Al	-0.24	0.25	**0.24**	**0.27**	**0.28**	-0.13	-0.14	-0.19
Mg	**0.27**	0.20	-0.19	-0.34	-0.23	-0.02	**0.28**	**0.26**
Ca	0.22	**0.28**	**0.26**	**0.22**	-0.27	0.12	0.14	**0.38**
Fe	-0.30	0.07	0.12	**0.40**	0.17	**0.29**	**0.27**	-0.13
Cu	0.20	0.04	-	-	**0.22**	-0.24	-	-

Table 11 - Experimental variable loadings in principal components (PCA), eigenvalues, and variances for the BHCU surface water quality dataset.

The PCA results obtained suggest that there is a seasonal difference, and the reason for this may be related to several factors such as seasonality, configuration of land use and land cover, spatial and temporal scale, and other intrinsic characteristics (XIAO et al., 2016; RODRIGUES et al., 2018).

The quartile sampling of Figure 6 showed that points 1, 2, and 3 were the ones that stood out due to the occurrence of concentrations between the evaluated parameters, which may be related to erosive features and anthropic interventions such as cattle raising, pasture reform, and areas of silviculture harvested, given that the latter alters the concentrations of nutrients and sediments in water bodies (RODRIGUES et al., 2019).

Points 1, 2, and 3 are located in pasture areas, most of which are intended for cattle raising, which may be influencing the increase in the concentrations of the parameters since the highest concentrations of TP are in these areas since this parameter is closely associated with the analysis of the impacts of agricultural activities (ASSIS and AZEVEDO LOPES, 2017) so much so that in the autumn PC1, spring and summer PC1 this parameter was presented.

Another aggravating factor is the suppression of riparian vegetation, which is essential in containing/barrier the entry of organic and inorganic elements into the water body (CONNOLLY et al., 2015) since riparian zones have long been known to help stabilize biodiversity and water quality (SOUZA et al., 2013; FERNANDES et al., 2014; KEIR et al., 2015)—being very degraded in points 2 and 3.

Figure 8 presents the concentration of some parameters for the entire period that stood out in the analysis, as Alvareda et al. (2020) demonstrated.

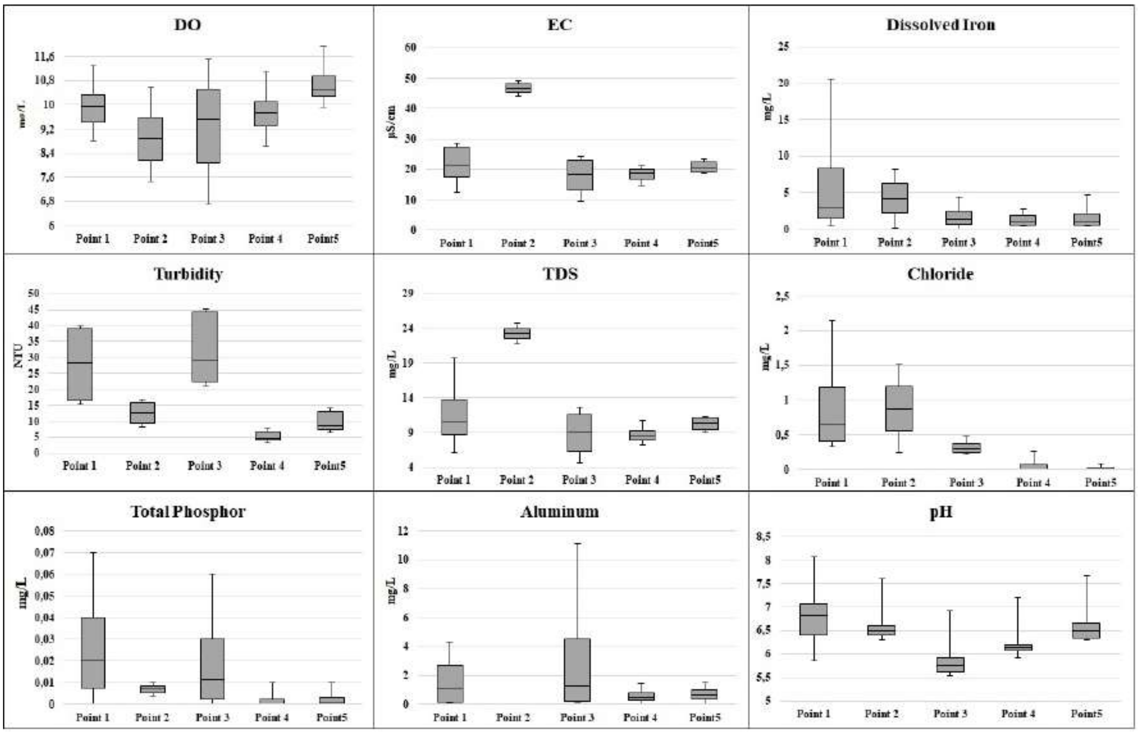

Figure 8 - Boxplot of quartiles of parameters classified by resolution 357/2005 by contribution area for the entire period.

Still, in point 3, in addition to the influence of agriculture and livestock, there is also the action of forestry harvest activities and the erosion processes installed in the river channel (Figure 9) that may influence the entry of elements/materials.

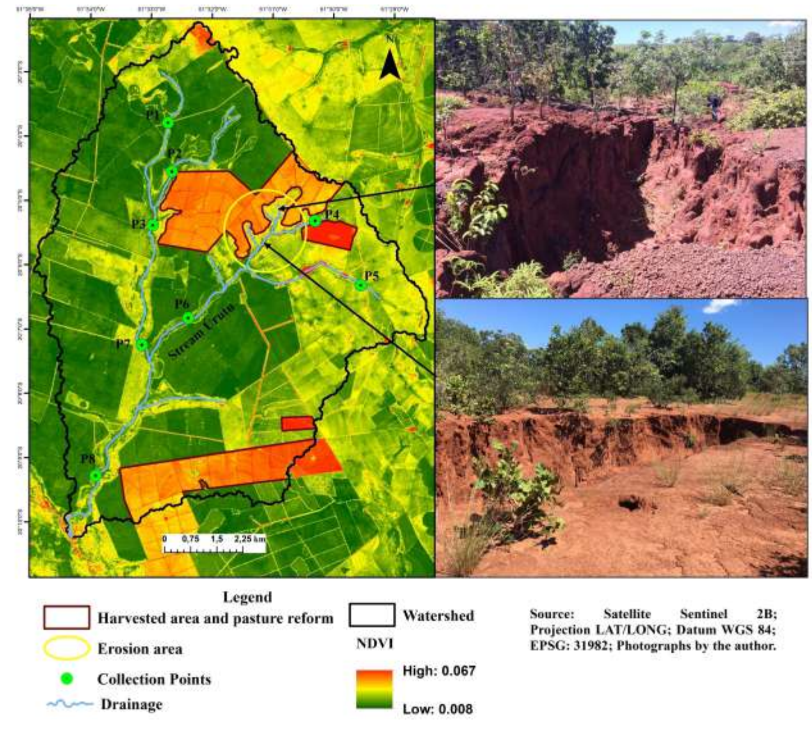

Figure 9 - Location of erosion area and pasture harvested/reformed area identified at BHCU. Fonte: Summer Normalized Difference Vegetation Index (NDVI) mapping, field photographs.

The occurrence of the concentration of some parameters not only in point 3 but also in points 1 and 2 has been observed since the first collection, such as the parameters turbidity, TDS, Al, pH, and Fe. The chemical characteristics of the soil may influence these concentrations, as Fe (IPT, 1981) and Al are abundant in the soils of the Brazilian Cerrado.

Points 4 and 5 were the ones that presented the concentrations of the parameters with the best classifications, which may be related to the classes of land use and land cover, as both presented together the largest area of planted forests and natural vegetation.

CONCLUSION

The methodology adopted in monitoring water quality helped in the seasonal analysis of the watershed as seasonality showed it was related to changes in water quality, mainly derived from rainfall, geological/soil and use, cover, and management changes of the land, which are partly reflected in the limits established by the legislation and in the specificities of the domain of the Brazilian cerrado. There was more emphasis on iron concentrations, derived from the Santo Anastácio sandstones, in a more significant proportion in the Vale do Rio do Peixe, and aluminum in the soils.

Interactions between water quality parameters followed conventional associations such as ALK and EC, TDS and EC, Color and Turbidity, TSS and Turbidity, EC and Ca, EC and Mg. These associations and interactions were detected in Pearson's correlation and in principal component analysis - PCA, which also suggested a seasonal difference in water quality.

Having obtained the results, we suggest adopting measures such as the recomposition and recovery of the riparian vegetation in the spring areas, especially in point 2; recovery of areas affected by erosion processes installed in the basin; the implementation of soil conservation techniques on the properties and neighboring roads and the improvement in land management, both in terms of soil and animals, respecting seasonality and slopes, and focusing on livestock; constant monitoring of surface water quality and fencing and maintenance of riparian forests.

Seasonal monitoring of water quality, which should be required by law in case of intensified land use, may serve as a support tool for future studies of analysis of environmental fragility and soil loss, contributing to the planning and management of watersheds.

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