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RELATIONSHIP BETWEEN LAND USE AND OCCUPATION AND WATER QUALITY IN THE CUBATÃO RIVER BASIN, SANTA CATARINA STATE, BRAZIL

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ABSTRACT
The Cubatão River watershed, located in Joinville and Garuva, Santa Catarina, Brazil, supplies water to approximately 70% of Joinville's population. This study examines the relationship between land use, occupation, and water quality in this essential basin. Using satellite imagery, we mapped land use and land cover, followed by multiple linear regression and cluster analyses of water quality data. Findings show that unregulated urbanization and intensive agriculture are key contributors to water quality degradation. Urbanization leads to increased soil sealing, reduced infiltration, and higher surface runoff, which carries pollutants to water bodies. Agriculture, as a major source of nutrients and pesticides, promotes eutrophication and water contamination. Cluster analysis identified distinct groups based on water quality and land use, revealing spatial variability across the basin. These results suggest that specific management approaches tailored to each area's land use are needed to improve water quality. This study highlights the critical role of soil conservation practices and integrated watershed management in mitigating the negative impacts of land use on water resources, thereby supporting sustainable water quality for the Cubatão River Basin.

Keywords: Water Quality Index. Multiple Linear Regression. Trophic State Index. Joinville. Braço River.

RELAÇÃO ENTRE O USO E OCUPAÇÃO DO SOLO E A QUALIDADE DAS ÁGUAS NA BACIA HIDROGRÁFICA DO RIO CUBATÃO, ESTADO DE SANTA CATARINA, BRASIL

RESUMO
A bacia hidrográfica é uma importante unidade de análise ambiental, e a relação entre o uso e ocupação do solo e a qualidade das águas é um tema de crescente interesse e relevância

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na gestão dos recursos hídricos. A bacia do rio Cubatão, localizada nos municípios de Joinville e Garuva, Santa Catarina, é vital para o abastecimento de água de aproximadamente 70% da população joinvilense. Nesse sentido, o objetivo do presente estudo foi analisar a relação entre o uso e ocupação do solo na bacia do rio Cubatão, com a qualidade das águas superficiais. Para tanto, foi realizado mapeamento do uso e cobertura do solo a partir de imagens de satélite, e a partir de dados de qualidade de água foram realizadas análises estatísticas como regressão linear e análise de agrupamento. Dentre os principais resultados tem-se que a urbanização desordenada e a agricultura intensiva são as principais causas de degradação da qualidade da água. A urbanização aumenta a impermeabilização do solo, reduz a infiltração de água e eleva o escoamento superficial, transportando poluentes para os corpos d'água. A agricultura contribui significativamente com nutrientes e pesticidas, resultando em eutrofização e contaminação das águas. As análises multivariadas de agrupamento revelaram grupos distintos de qualidade de água e uso do solo, destacando a variabilidade espacial e a necessidade de abordagens de gestão específicas para diferentes áreas da bacia. Nesse sentido, o estudo reforça a importância de práticas de conservação do solo e gestão integrada das bacias hidrográficas para melhorar a qualidade da água.

Palavras-chave: Índice de Qualidade das Águas. Regressão Linear Múltipla. Índice de Estado Trófico. Joinville. Rio do Braço.

RELACIÓN ENTRE EL USO Y OCUPACIÓN DEL SUELO Y LA CALIDAD DEL AGUA EN LA CUENCA DEL RÍO CUBATÃO, ESTADO DE SANTA CATARINA, BRASIL

RESUMEN
La cuenca hidrográfica es una unidad importante de análisis ambiental, y la relación entre el uso y la ocupación del suelo y la calidad del agua es un tema de creciente interés y relevancia en la gestión de los recursos hídricos. La cuenca del río Cubatão, ubicada en los municipios de Joinville y Garuva, Santa Catarina, es vital para el abastecimiento de agua de aproximadamente el 70% de la población de Joinville. Por lo tanto, el objetivo de este estudio fue analizar la relación entre el uso y la ocupación del suelo en la cuenca del río Cubatão y la calidad de las aguas superficiales. Para ello, se realizó un mapeo del uso y la cobertura del suelo mediante imágenes satelitales, y se realizaron análisis estadísticos como regresión lineal y análisis de conglomerados utilizando datos de calidad del agua. Entre los principales hallazgos se encuentra que la urbanización no planificada y la agricultura intensiva son las principales causas de la degradación de la calidad del agua. La urbanización aumenta la impermeabilidad del suelo, reduce la infiltración de agua y aumenta la escorrentía superficial, transportando contaminantes a los cuerpos de agua. La agricultura contribuye significativamente a la introducción de nutrientes y pesticidas, lo que resulta en eutrofización y contaminación del agua. Los análisis multivariados de conglomerados revelaron grupos diferenciados de calidad del agua y uso del suelo, lo que pone de relieve la variabilidad espacial y la necesidad de enfoques de gestión específicos para las diferentes zonas de la cuenca. En este sentido, el estudio refuerza la importancia de las prácticas de conservación del suelo y la gestión integrada de cuencas hidrográficas para mejorar la calidad del agua.

Palabras clave: Índice de Calidad del Agua. Regresión Lineal Múltiple. Índice de Estado Trófico. Joinville. Río Braço.

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1 INTRODUCTION

River basins play a critical role in supplying water to cities and are essential for environmental sustainability and the quality of life of urban populations. However, water quality issues and the need for effective monitoring and protection are increasingly pressing challenges in this context (Custódio *et al*., 2023).

The relationship between land use, occupation, and water quality is a subject of growing interest and relevance in the field of environmental management and water resources. Changes in land use, such as urbanization, intensive agriculture, and industrialization, can significantly alter the physical, chemical, and biological characteristics of surface and groundwater. These changes can affect public health, biodiversity, and recreational and economic uses of water (Menezes *et al*., 2016). For example, intense urbanization contributes to increased soil sealing, which reduces water infiltration and increases surface runoff, which carries pollutants into water bodies (Simeonov *et al*., 2003). Agriculture, in turn, is a major source of nutrients and pesticides that, when leached or runoff, can cause eutrophication and contamination of water resources (Sodré, 2012).

Several studies have proved that the increase in anthropogenic activities is directly related to the degradation of water quality. The study by Tong & Chen (2002) examined the relationship between land use and surface water quality. The authors emphasized that urbanized, agricultural, and industrial areas have a significant impact on water quality degradation due to the increase in pollutants such as nutrients, heavy metals, and sediments. They used predictive models to show how different land use practices can alter surface water quality, providing a basis for environmental management policy.

Allan (2004) examined how land use and land cover can affect surface water ecosystems. The paper highlighted that intensive agricultural and urban activities lead to significant increases in nutrients and pollutants in water bodies, altering the biological composition and overall quality of aquatic ecosystems. The paper suggests that conservation strategies should focus on integrated watershed management to mitigate these impacts. This article examines the relationship between vegetation cover and soil erosion in mountainous watersheds. In addition, the removal of vegetation for agriculture or urbanization significantly increases soil erosion, leading to higher sediment loads in waterways. Maintaining adequate vegetation cover is a critical strategy for maintaining water quality (Ouyang *et al*., 2010). Finally, Pacheco and Fernandes (2016) discussed land use conflicts in river basins and how they amplify the presence of nitrates in river water. In this study, intensive agricultural

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practices and urban development were identified as the main sources of nitrate pollution.

In the Brazilian context, watershed conservation plays a crucial role in the protection of water resources. The Cubatão River, located in the municipalities of Joinville and Garuva, Santa Catarina, is significant to the region, providing public water supply to approximately 70% of Joinville's population. The watershed has a mix of uses and occupations, including protected areas of Atlantic forest, agriculture, industrial areas, and urban areas (Oliveira *et al.*, 2017). Monitoring water quality is essential for formulating public policies and implementing pollution control measures. Standardized methods for water and effluent analysis, such as those described by the American Public Health Association et al. (2017), provide the necessary basis for comparing data and assessing the effectiveness of mitigating actions. In Brazil, water quality indices such as the water quality index (WQI) and the trophic state index (TSI), used by entities such as CETESB (2023), are important tools for monitoring and communicating the state of health of aquatic ecosystems. Regional studies, such as those carried out by Araújo et al. (2018) and Oliveira et al. (2017), highlight the spatial and temporal variability of water quality and the need for specific local approaches. In the study by Santos and Souza (2019), the authors point out that the WQI is an important indicator for assessing water quality and guiding public policies. The research identified that the Cubatão river basin faces significant challenges due to industrial and urban pollution, and suggests stricter management measures to mitigate these impacts.

This work therefore seeks to explore and discuss the impact of land use on water quality indexes in the Cubatão River basin using land use mapping methods and statistical analysis of water quality data, such as multiple linear regression and cluster analysis.

2 METHODOLOGY

2.1 STUDY AREA

The study area comprises the Cubatão River Basin (BHRC), located in the municipalities of Joinville and Garuva, in the northeast of the state of Santa Catarina, Brazil (Figure 1). The basin covers an area of approximately 490 km², and its main channel is 90 km long (Oliveira *et al.*, 2017).

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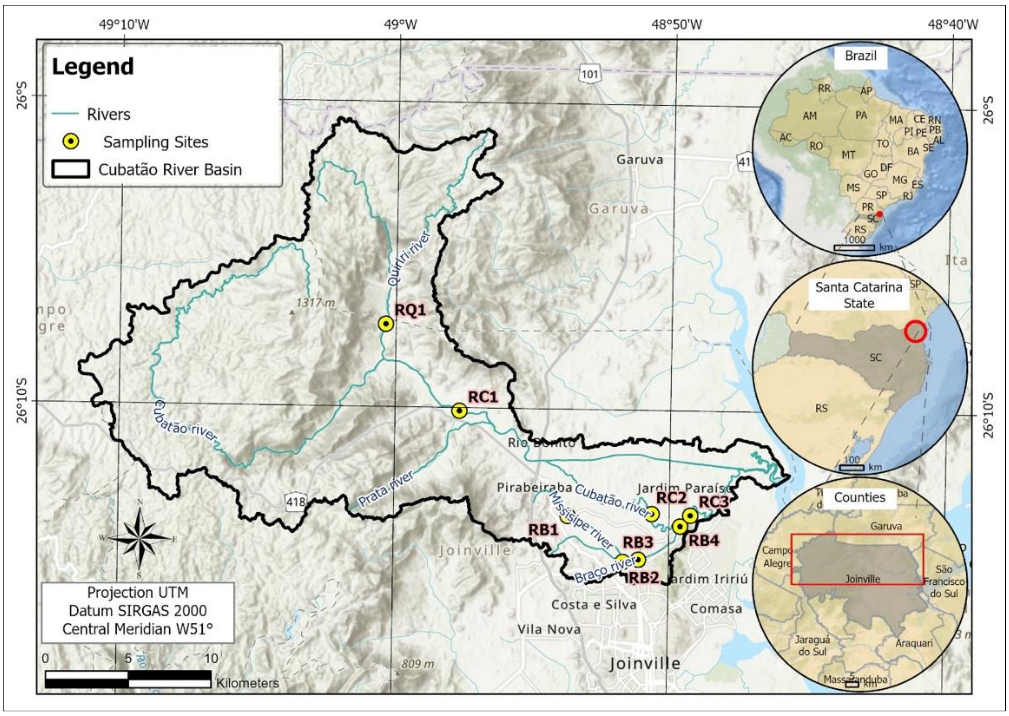
Figure 1

Location of the Cubatão River Basin and the points monitored.



The BHRC is of exceptional importance to the region, as it is responsible for the public water supply of approximately 70% of the population of Joinville, the largest municipality in the state in this segment (616,317 inhabitants). This dynamism is directly related to the local economy, which has been driven by the industrial sector since the city's foundation. In this sense, it is a basin with a mixture of uses and occupations: preserved areas of Atlantic forest, agriculture, and industrial areas, among others.

2.2 COLLECTION POINTS

The data sample consists of a total of 08 sampling points located in different geographical contexts of the BHRC, spatialized as shown in Figure 1. Table 1 shows the basic information for each point, such as geographic coordinates, altitude (m), name of the watercourse, name of the watershed, and area of contribution (km²). Surface water samples were collected monthly throughout 2019.

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Table 1

Information on the water collection points.

Poin	Latitude	Longitude	Altitude	Watercourse	Watershed	Contribution area
RQ1	26°7'20.108"S	49°0'23.574"W	93.74	Rio Quiriri	Rio Quiriri	96.73
RC1	26°10'9.800"S	48°57'42.292"	43.23	Rio Cubatão	Rio Cubatão	331.83
RC2	26°13'25.651"	48°50'38.288"	7.42	Rio Cubatão	Rio Cubatão	405.31
RC3	26°13'26.542"	48°49'14.87"W	1.07	Rio Cubatão	Rio Cubatão	450.40
RB1	26°13'31.594"	48°53'41.666"	14.97	Rio Mississipe	Rio do	7.04
RB2	26°15'0.079"S	48°51'40.918"	7.16	Rio	Rio do	13.26
RB3	26°14'56.358"	48°51'7.598"W	5.34	Rio do Braço	Rio do	32.13
RB4	26°13'50.519"	48°49'37.062"	1.29	Rio do Braço	Rio do	41.34

2.3 ANALYSIS OF WATER QUALITY DATA

Different statistical tests were applied to the temporal sample of water quality data to check its consistency, as well as its relationship with land use and occupation in the watershed. The Water Quality Index (WQI) was used as the analysis methodology. This was obtained using the parameters of altitude (m), water temperature (ºC), dissolved oxygen in the water (mg/L), thermotolerant coliforms (NMP/100mL), pH, biological oxygen demand (5 days, in mg/L), total nitrogen (mg/L), total phosphorus (mg/L), turbidity (UNT), total solids (mg/L) (CETESB, 2020).

2.3.1 Linear regression

To perform the multiple linear regression analysis and to understand the relationship between the WQI and the types of land occupation, the measurements of the percentages of land cover for each contribution area (corresponding to each sampling point) were used as independent variables, and the dependent variable was the WQI.

The assumptions of linearity, normality of residuals, homoscedasticity and independence of errors were checked. The multiple regression analysis estimated the coefficients of the independent variables, their statistical significance, and the quality of the model fit using the coefficient of determination (R^2).

2.3.2 Cluster, factor, and principal component analysis

The set of water quality data from the Cubatão river basin was evaluated using multivariate analysis, with *cluster* analysis, factor analysis (FA) and principal component analysis (PCA) techniques (Simeonov *et al.*, 2003) to identify points with similar characteristics and the possible nature of the pollution.

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2.3.3 Trophic state index

The Cubatão river basin is considered a lotic environment, so the equation used to define the trophic state index was that proposed by Lamparelli (2004) (Equation 1). In addition, the table used to classify the trophic state index was that of the CETESB, which classifies trophic state values for lotic environments according to the modified Carlson index, as shown in Table 2.

$$IET_L = 10 * \left[6 - \left(\frac{0.42-0.36*\ln(P)}{ln2}\right)\right] - 20 \qquad (1)$$

In which:

IET_L= Lamparelli's trophic state index (2004)
P = total phosphorus concentration (µg.$^{L-1}$)
ln = natural logarithm

Table 2

Trophic status classification for lotic environments, according to Carlson's index (1977)

Trophic State Classification - Lotic Environments		
Category (Trophic State)	**Weighting**	**PT (µg/L)**
Ultraoligotrophic	IET ≤ 47	P ≤ 13
Oligotrophic	47 < IET ≤ 52	13 < P ≤ 35
Mesotrophic	52 < IET ≤ 59	35 < P ≤ 137
Eutrophic	59 < IET ≤ 63	137 < P ≤ 296
Supereutrophic	63 < IET ≤ 67	296 < P ≤ 640
Hypereutrophic	IET > 67	640 < P

Source: Adapted from CETESB (2013).

Carlson (1977) developed a classification of the trophic state of aquatic environments based on three types of parameters: chlorophyll-a concentration, water transparency as measured by the Secchi disk, and total phosphorus concentration. Although some authors use all three parameters or only phosphorus or chlorophyll-a, according to this author, any one of them can be used alone for this analysis. Therefore, in this study, EIT was determined using total phosphorus concentration.

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2.4 MAPPING LAND USE AND COVER

Land use and land cover data were obtained from the MAPBIOMAS project website (MAPBIOMAS, 2019; Souza *et al.*, 2020) for the year 2019. The downloaded data were clipped to the contribution areas of each water catchment. The whole procedure was carried out in ArGIS® software, using the UTM projection, central meridian W51° and SIRGAS2000 datum. Ten land use classes were used: forest formation; planted forest; pasture; mosaic of agriculture and pasture; urban area; other non-vegetated areas; river, lake, or ocean; temporary crops; other temporary crops; and mangroves.

For each contribution area, corresponding to each sampling point, the area, and percentage of each class of land use and cover was calculated. Figures 2 and 3 show the spatial distribution of the contribution area of each sampling point, and the respective contribution areas are shown in Table 1.

Figure 2

Contribution area of the water monitoring points on the Cubatão and Quiriri rivers.

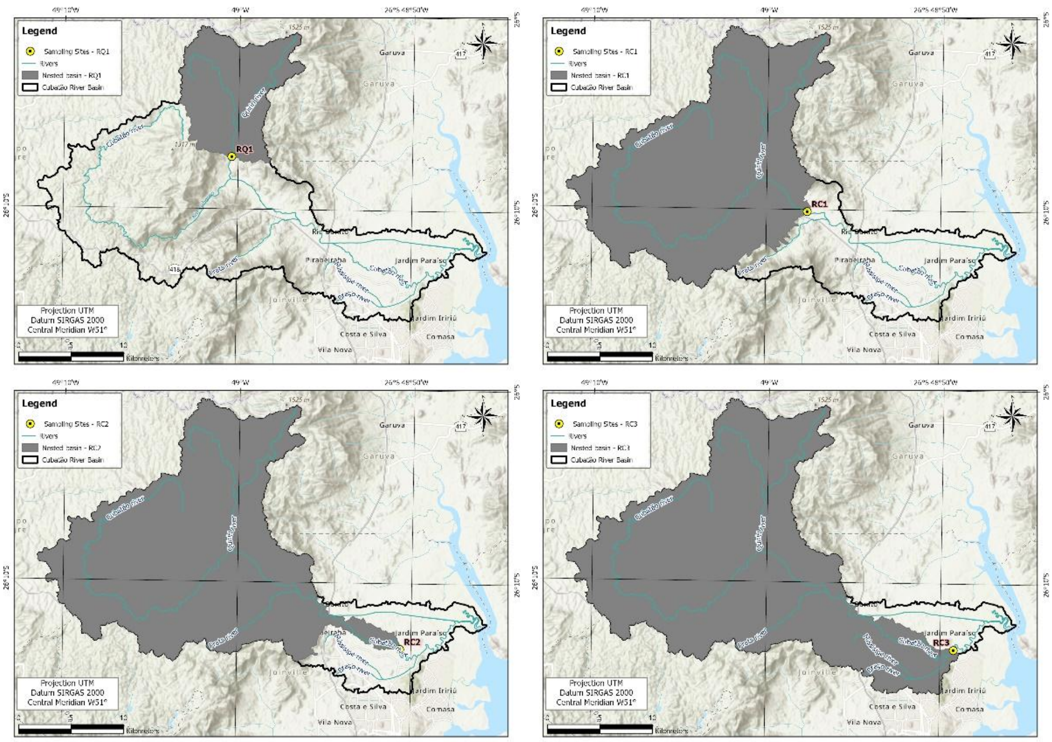

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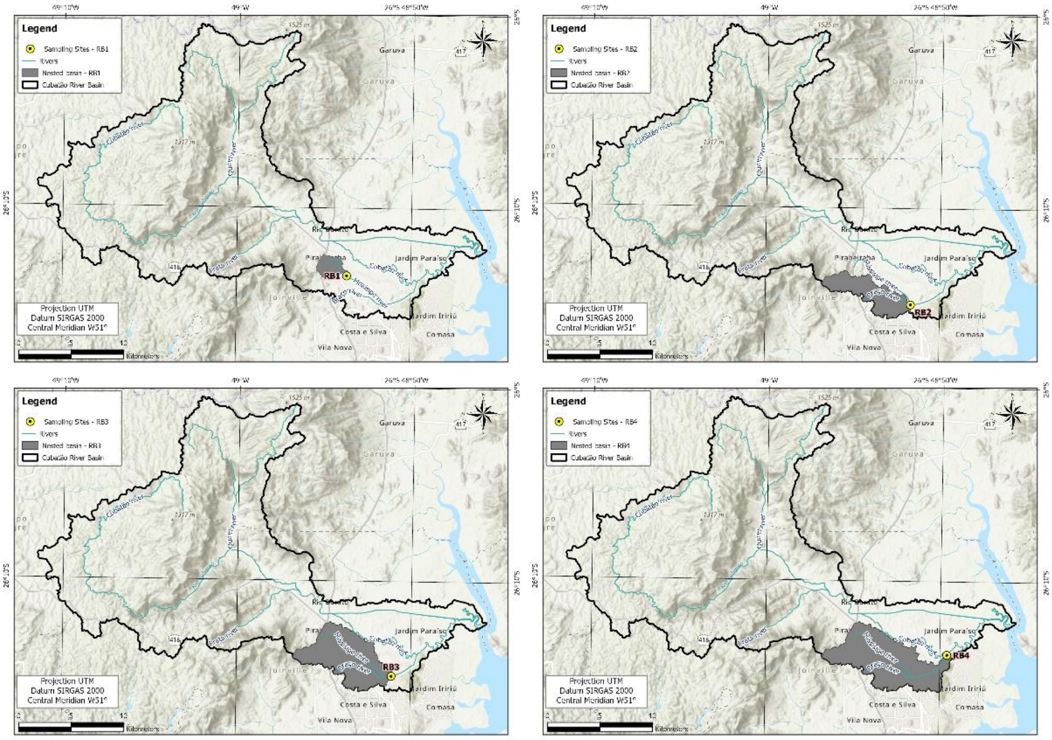
Figure 3

Contribution area of the water monitoring points on the Braço River.



3 RESULTS AND DISCUSSION

For each contributing area of the points, the coverage areas for each type of use were calculated, as shown in Figure 4 and Table 2. It can be seen that the predominant land cover is forest (Atlantic Forest) for all the stations. Particularly noteworthy is the Braço River basin, which has a larger urban area than the other monitoring points.

Figure 4

Land use and cover map of the Cubatão river basin.

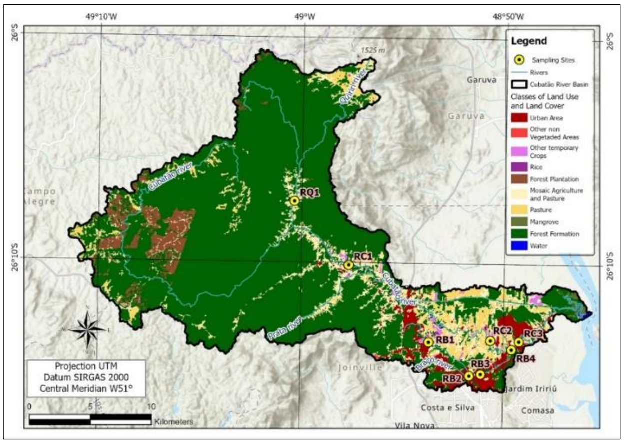


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Table 2

Land cover (%) and WQI, according to the area of contribution of each point analyzed.

	Soil coverage									
Point	Forestry training	Planted Forest	Pasture	Agriculture and Grassland	Urban area urban	Other non-vegetated areas	River, Lake or Ocean	Temporary crops	Other Temporary Crops	WQI
RQ1	89.4	1.0	4.8	4.8	0.0	0.0	0.0	0.0	0.0	68.2
RC1	85.8	5.8	3.5	4.7	0.1	0.0	0.0	0.0	0.1	68.8
RC2	83.4	4.8	4.1	6.9	0.3	0.0	0.0	0.0	0.3	65.6
RC3	78.8	4.4	4.9	8.1	3.3	0.1	0.0	0.0	0.5	59.4
RB1	56.1	0.0	3.5	10.3	28.0	0.5	0.0	0.2	1.3	51.6
RB2	54.3	0.0	1.6	9.5	32.8	0.8	0.0	0.0	1.0	43.7
RB3	43.3	0.0	9.5	16.7	27.2	0.6	0.2	0.4	2.1	52.9
RB4	41.0	0.0	9.7	16.4	30.2	0.4	0.2	0.4	1.8	50.8

The first-degree equation obtained from the multiple linear regression analysis indicated that the WQI depends mostly on the urban area, as follows:

WQI = 66.32 - 0.5707 * urban area (2)

The statistical significance was $p < 0.001$ and the quality of the model fit using the R^2 coefficient of determination was 90.07%. The inclusion of urban area as an explanatory variable in the model and its negative coefficient (equation 1) suggest that the presence of urbanized areas is associated with deterioration of water quality. This means that for each unit increase in urbanization, a decrease of 0.5707 in the WQI is expected, holding the other factors constant.

In addition, the model shows that about 90% of the variation in WQI can be explained by urban occupation. This high percentage indicates that urban occupation is a key factor in determining water quality in the Cubatão River Basin region. However, it is important to note that other factors not included in the model may also contribute to water quality, such as industrial pollution, agricultural activities, and inadequate domestic sewage disposal. Regarding the conservation of the Cubatão River basin, the relationship identified between the urban area and the WQI highlights the need to adopt measures to preserve and protect the water catchment and recharge areas within the basin. Haphazard urbanization and a lack of proper planning lead to soil sealing, increased surface runoff, and possible water

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contamination from urban and industrial waste. It is therefore essential to implement soil conservation practices and appropriate land use to minimize negative impacts on water quality.

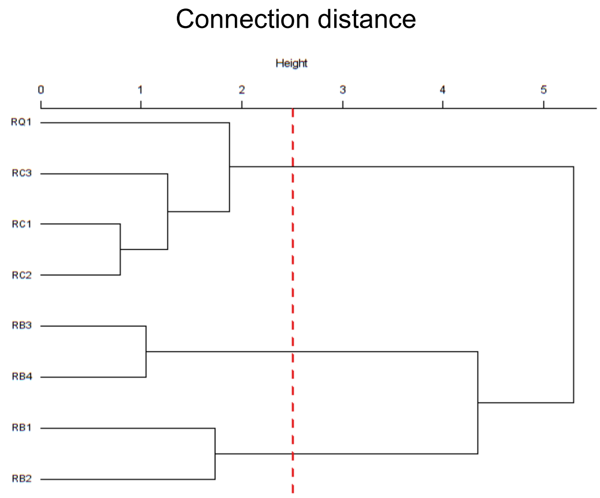
With regard to public sanitation policies, the results of the analysis reinforce the importance of investments in wastewater treatment infrastructure and drinking water supply by the municipality of Joinville. The presence of urban settlements is associated with a deterioration of water quality, indicating the need for adequate wastewater treatment systems to minimize water pollution.

The United Nations Sustainable Development Goals on clean water and treated wastewater are highlighted in this context. The results of the analysis show that urban settlement has a significant impact on water quality. It is therefore important to align watershed conservation measures and public sanitation policies with sustainable development goals, such as Goal 6 - Drinking Water and Sanitation, which aims to ensure the availability and sustainable management of water and sanitation for all.

To assess temporal and spatial trends, multivariate cluster analysis was performed on land cover and water quality data. The standardized clustering procedure for land cover produced three distinct groups with similar characteristics in terms of land cover types (Figure 5): Group 1 (RQ1, RC3, RC1, and RC2) with greater forest formation, Group 2 (RB3 and RB4) with less forest formation and significant presence of urban occupation, and Group 3 (RB1 and RB2) with greater presence of non-vegetated areas.

Figure 5

Cluster dendrogram with land cover data from the Cubatão River Basin.



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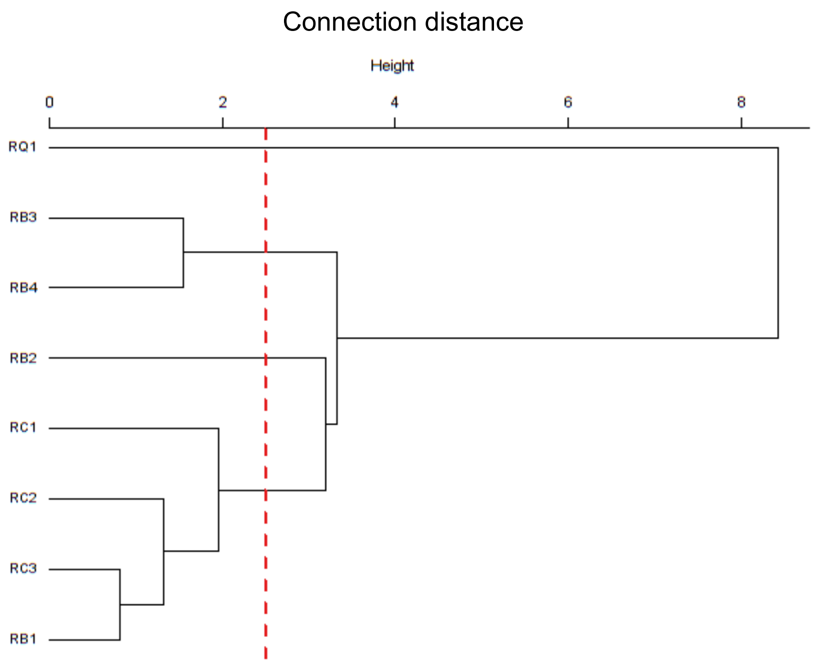
For the WQI, 4 distinct groups with similar characteristics were generated (Figure 6): Group 1 (RQ1), located in a more preserved area and with a high value for WQI, Group 2 (RB3 and RB4) with similarities in both land occupation and WQI, Group 3 (RB2) whose WQI was the lowest among the points analyzed and Group 4 (RC1, RC2, RC3 and RB1) with similar WQI values and pasture formation.

Figure 6

Cluster dendrogram with water quality data from the Cubatão River Basin.



The grouping of sections means that for a generic assessment of water quality in the Cubatão River basin, only one site in each group can serve as a good representation of the spatial assessment of water quality throughout the drainage network. In this way, the number of points to be monitored within a basin can be reduced, and consequently the operational expenses, without losing the precision of the results. For the case studied, only four points could be analyzed: RQ1, (RB3 or RB4), RB2, and (RC1, RC2, RC3 or RB1). Simeonov (2003) also proposes this classification. To compare and analyze the water quality parameters between the monitored points, Factor Analysis (FA) and Principal Component Analysis (PCA) were applied to the normalized data.

The best behavior of the water quality variables in the Cubatão River was that they were composed of four components (C1, C2, C3 and C4). The selection of the number of components was based on the principles suggested by Jolliffe (2002), i.e., an accumulated

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percentage of the total variance between 70 and 90% gives a reasonable idea of the representation of the original variance. A cumulative percentage of the total variance of the original data of 70% was adopted as the criterion for selecting the principal components, which was also used in the work of Menezes (2016).

Principal component analysis expresses the relationship between factors and variables, and makes it possible to identify the variables with the most interrelationships in each component. The first component evaluated is related to the variables indicating organic nutrient loads and the use of nitrogen compounds (total nitrogen, total solids, and BOD5) (Fleck, 2015). The second component is associated with temperature and pH, which can be associated with industrial discharges (Silva, 2022). The third component relates to trophic state index and turbidity, which may be associated with diffuse pollution by materials from agricultural and urban areas (Sodré, 2012). The fourth component associates thermotolerant coliforms, which are characteristic of the presence of domestic wastewater.

In order to maximize the variance between the factors, the axes were transformed using the Varimax algorithm. This process maximizes the variance between the factors by changing the characteristic root without affecting the proportion of the total variance explained by the set (Menezes, 2016).

With this transformation, component 5 appears to help explain the composition of the WQI, which associates total phosphorus, which can be characteristic of the presence of fertilizers in the watershed.

It is important to note that to rigorously assess the quality of water bodies; one should not be restricted to just one quality index. Therefore, as a complementary way of better understanding the water quality of the Cubatão river basin, the trophy index was assessed for the different points, as shown in Table 3.

Table 3

Calculation of the trophic state index for each water collection point in the BHRC during 2019.

	Points							
Months	**RQ1**	**RC1**	**RC2**	**RC3**	**RB1**	**RB2**	**RB3**	**RB4**
January	19.41	15.73	21.60	25.79	28.79	24.71	25.12	28.82
February		12.69	15.53	18.26	27.37	52.26	24.49	25.81
March		12.13	15.83	15.41	19.99	22.38	23.88	25.12
April	21.43	19.24	25.23	17.48	22.57	27.96	21.95	22.28
May		12.13	30.01	12.13	12.13	23.14	24.83	20.87
June		12.13	12.13	12.13	21.67	12.13	12.13	17.18

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July	12.13	12.13	12.13	14.44	25.91	23.50	20.38	26.61
August		12.13	12.13	12.13	27.53	17.80	12.13	12.13
September		12.13	12.13	15.66	24.02	23.77	18.57	21.98
October	0.17	12.13	0.17	18.93	25.34	27.31	24.65	25.20
November		14.63	14.42	20.33	29.63	29.85	24.22	27.20
December		13.62	14.68	19.81	29.47	27.25	23.38	25.63
Annual	**13.29**	**13.40**	**15.50**	**16.87**	**24.54**	**26.00**	**21.31**	**23.24**

For all the points analyzed, the IETL was less than 27, with the classification found for water bodies being ultra-oligotrophic (Araújo, 2018), using Equation 1 for lotic environments. These clean water bodies with very low nutrient productivity and low nutrient concentrations are not harmful to their use. Despite the urban occupation of the Cubatão river basin, the ultra-oligotrophic environment is still present, leading to the decision to intensify environmental preservation and monitoring actions in the region.

4 CONCLUSION

Based on the results presented, the analysis showed that urbanization has a significant impact on the water quality of the Cubatão River Basin, indicating that an increasing urban population is associated with a deterioration of the Water Quality Index (WQI). This result is supported by the R^2 coefficient of determination of 90.07%, which indicates that the urban population is one of the main factors influencing the water quality, explaining about 90% of the variation observed in the WQI.

The results of the multivariate and cluster analysis indicated that land use, occupation, and water quality are closely related, with different areas of the watershed exhibiting different water quality patterns based on the type of land use and land cover. The application of Principal Component Analysis (PCA) and Factor Analysis (FA) made it possible to identify the main factors contributing to the variation in water quality, such as organic nutrients, pH, temperature and the presence of thermotolerant coliforms, associated with different sources of pollution, including domestic sewage and industrial pollution.

The classification of water bodies as ultra-oligotrophic, based on the Trophic State Index (TSI), suggests that the Cubatão River basin still maintains relatively high water quality, with low nutrient concentrations and high purity, despite urban pressures. However, this state requires continuous and rigorous monitoring, as well as intensified conservation efforts to prevent increasing urbanization from affecting water quality in the future.

In short, the results highlight the importance of public policies that address basic sanitation and environmental protection in an integrated manner, especially in water catchment and recharge areas. The study reinforces the need to align these policies with the Sustainable Development Goals (SDGs), in particular SDG 6, which aims to guarantee drinking water and sanitation for all, to protect and preserve the quality of water resources in urbanized areas.

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REFERENCES

Allan, J. D. (2004). Landscapes and riverscapes: The influence of land use on stream ecosystems. Annual Review of Ecology, Evolution, and Systematics, 35, 257-284. https://doi.org/10.1146/annurev.ecolsys.35.120202.110122

American Public Health Association, American Water Works Association, & Water Environment Federation (Eds.). (2012). Standard methods for the examination of water and wastewater (22nd ed.). Washington, D.C.: American Public Health Association.

Araújo, D. R., Mendonça, A. S. F., & Reis, J. A. T. (2018). Análise de variação e comparação de índices de estado trófico: reservatórios dos aproveitamentos hidrelétricos de Rio Bonito e Suíça. Engenharia Sanitária e Ambiental, 23(1), 55-62. https://doi.org/10.1590/S1413-41522018162462

Bridgewater, L. L., et al. (Eds.). (2017). Standard methods for the examination of water and wastewater (23rd ed.). Washington, D.C.: American Public Health Association.

Carlson, R. E. (1977). A trophic state index for lakes. Limnology and Oceanography, 22(2), 361-369. https://doi.org/10.4319/lo.1977.22.2.0361

CETESB - Companhia Ambiental do Estado de São Paulo. (2020). Índice de Qualidade das Águas: Apêndice D. São Paulo: CETESB. Disponível em: https://cetesb.sp.gov.br/aguas-interiores/wp-content/uploads/sites/12/2021/09/Apendice-E-Indice-de-Qualidade-das-Aguas.pdf.(In portuguese)

Revista
ARACÊ
ISSN: 2358-2472

Custódio, M. R., et al. (2023). Water quality assessment in urban watersheds: challenges and perspectives. Environmental Monitoring and Assessment, 195(6), 302. https://doi.org/10.1007/s10661-023-11111-1

Fleck, L., Eyng, E., & Tavares, M. H. F. (2015). Remoção biológica de nitrogênio em efluentes líquidos: uma revisão. Revista EIXO, 4(2), 43-55. https://doi.org/10.19123/eixo.v4i2.293

Jolliffe, L. T. (2002). Principal component analysis (2nd ed.). New York: Springer. https://doi.org/10.1007/b98835

Kinzelman, J. L., et al. (2005). Use of IDEXX Colilert-18® and Quanti-Tray/2000 as a Rapid and Simple Enumeration Method for the Implementation of Recreational Water Monitoring and Notification Programs. Lake and Reservoir Management, 21(1), 73-77. https://doi.org/10.1080/07438140509354414

Lamparelli, M. C. (2004). Grau de trofia em corpos d'água do estado de São Paulo: avaliação dos métodos de monitoramento (Tese de Doutorado). Universidade de São Paulo, São Paulo. https://www.teses.usp.br/teses/disponiveis/41/41134/tde-20032006-075813/publico/TeseLamparelli2004.pdf

MapBiomas. (2022). Coleção 8 da Série Anual de Mapas de Uso e Cobertura da Terra do Brasil. Acessado em 22 de abril de 2022, de https://storage.googleapis.com/mapbiomas-public/initiatives/brasil/collection_8/lclu/coverage/brasil_coverage_2019.tif

Menezes, J. P. C., Bittencourt, R. P., Farias, M. S., Bello, I. P., Fia, R., & Oliveira, L. F. C. (2016). Relação entre padrões de uso e ocupação do solo e qualidade da água em uma bacia hidrográfica urbana. Engenharia Sanitária e Ambiental, 21(3), 519-534. https://doi.org/10.1590/S1413-41522016145405

Oliveira, T. M. N., et al. (2017). Bacias Hidrográficas da Região de Joinville: Gestão e Dados (1st ed.). Joinville, SC: Editora Univille. https://www.univille.edu.br/account/editora/VirtualDisk.html/downloadDirect/1145899/Bacias_hidrograficas_2017.pdf

Ouyang, W., Hao, F., Skidmore, A. K., & Toxopeus, A. G. (2010). Soil erosion and sediment yield and their relationships with vegetation cover in upper stream of the Yellow River. The Science of the total environment, 409(2), 396–403. https://doi.org/10.1016/j.scitotenv.2010.10.020

Pacheco, F. A. L., & Fernandes, L. F. S. (2016). Environmental land use conflicts in catchments: A major cause of amplified nitrate in river water. Science of the Total Environment, 548-549, 173-188. https://doi.org/10.1016/j.scitotenv.2015.12.155

Ribeiro, J. M. G., & Oliveira, T. M. N. (2017). Cartilha Geográfica: Bacias hidrográficas dos rios Cubatão (norte) e Cachoeira (1st ed.). Joinville, SC.

Santa Catarina et al. (2016). Atlas geográfico de Santa Catarina: Diversidade da natureza (Vol. 2). Editora da Udesc.

Revista
ARACÊ
ISSN: 2358-2472

Santos, R. C. L., & Souza, A. R. L. (2019). Índice de qualidade de água (IQA) como ferramenta de gestão ambiental na bacia hidrográfica do rio Cubatão, SC. Revista de Gestão Ambiental e Sustentabilidade, 8(1), 13-24.

Silva, E. S., Oliveira, D. D., Santos, F. M. A., & Lins, G. A. (2022). Correlação entre salinidade, temperatura e pH na área de influência do Porto da Cidade do Rio de Janeiro (Brasil) entre 2016 a 2018. Revista Sustinere, 10(1), 218-237. https://doi.org/10.12957/sustinere.2022.56684

Simeonov, V., Stratis, J. A., Samara, C., Zachariadis, G., Voutsa, D., Anthemidis, A., Sofoniou, M., & Kouimtzis, T. H. (2003). Assessment of the surface water quality in Northern Greece. Water Research, 37, 4119-4124. https://doi.org/10.1016/S0043-1354(03)00398-1

Sodré, F. F. (2012). Fontes difusas de poluição da água: Características e métodos de controle. Artigos Temáticos do AQQUA, 1, 9-16.

Souza, et al. (2020). Reconstructing three decades of land use and land cover changes in Brazilian biomes with Landsat Archive and Earth Engine. Remote Sensing, 12(17). https://doi.org/10.3390/rs12172735

Tong, S. T. Y., & Chen, W. (2002). Modeling the relationship between land use and surface water quality. Journal of Environmental Management, 66(4), 377-393. https://doi.org/10.1006/jema.2002.0593