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## Integration of environmental assessment models: A study of the impact on urban micro-watersheds in the Amazon-Brazil

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**ABSTRACT** - The micro-watershed of the Ouricuri river stands out for serving a large portion of the local population, however, the lack of sanitation, construction in permanent preservation areas, the release of effluents, and other high-impact activities influence the maintenance of the local ecosystem. The study aimed to promote the integration of environmental assessment methodologies such as Rapid Protocol for Environmental Assessment (RPEA) and interpolation by the Inverse Distance Weighted (IDW) method to evaluate the impact to which the study area is subject. The integration of techniques enabled to verify that the points P9 and P10 are in anoxic conditions, with values 60% below what is recommended by Resolution N° 357/05 of CONAMA for class 2 water, and the other points varying between high and moderate environmental risk, with emphasis on Points P4 and P5, corresponding to the Ouricuri River, where the situation requires greater attention. The Total Impact in the study area suggests that the Ouricuri micro-watershed needs immediate intervention, as in the sections of the Ouricuri River located in the commercial center and its tributaries, which are smaller streams, there is great pressure from the municipal sanitation system and buildings in protected areas, promoting serious changes to the local ecosystem and consequently to people's health.

Keywords: RPEA, IDW, Environmental Impact, Micro Basin.

## Integração de modelos de avaliação ambiental: Um estudo do impacto em Microbacias urbanas na Amazônia- Brasil.

**RESUMO** - A microbacia do rio Ouricuri se destaca por atender grande parte da população local, porém, a falta de saneamento, construção em áreas de preservação permanente, lançamento de efluentes e outras atividades de alto impacto influenciam na manutenção do local. ecossistema. O estudo teve como objetivo promover a integração de metodologias de avaliação ambiental como o Protocolo Rápido para Avaliação Ambiental (PRAA) e a Interpolação pelo Método Distancia Inversa Ponderada (IDIP) para avaliar o impacto ao qual área de estudo está sujeita. A integração das técnicas possibilitou verificar que os pontos P9 e P10 estão em condições anóxicas, com valores 60% abaixo do recomendado pela Resolução nº 357/05 do CONAMA para águas classe 2, e os demais pontos variando entre alto e moderado ambiental risco, com destaque para os Pontos P4 e P5, correspondentes ao Rio Ouricuri, onde a situação requer maior atenção. O Impacto Total na área de estudo sugere que a microbacia Ouricuri necessita de intervenção imediata, pois nos trechos do rio Ouricuri localizados no centro comercial e seus afluentes, que são riachos menores, há grande pressão do sistema de saneamento municipal e edificações em áreas protegidas, promovendo graves alterações no ecossistema local e consequentemente na saúde das pessoas.

Palavras-chave: PRAA, IDIP, Avaliação de Impacto Ambiental, Bacia Hidrográfica.

## Introduction

Considering that environmental impacts are caused by the interaction of human beings with the environment, understanding at which adverse levels human action can compromise an urban watershed is necessary (Zakaria et al., 2021). Population growth is directly linked to the progressive degradation of the environment and its natural resources, through the destruction of the native forest, contamination of the atmosphere, soil, and water. In aquatic environments, these impacts are associated with decreased soil permeability, removal of riparian vegetation, and increased domestic and industrial wastewater (Martins et al., 2017).

In the Amazon region, particularly in the northeast of Pará, with the intensification of industrialization, a significant and disorderly urban population growth has been noted. According to Pereira et al., (2021), such an effect directly influences environmental, social, and public health problems, as most municipalities have not adhered to the National Solid Waste Policy (PNRS) established since 2010 by the Brazilian federal government.

To create alternatives to remedy and alleviate this socio-environmental problem, authors such as Peeters et al., (2022) comment in their research that in recent decades there has been a significant advance in the methods for assessing environmental impacts. These methodologies are implemented worldwide as an instrument of environmental management, to measure the effects of human activities, as well as in the prevention of environmental degradation.

One of the main assessment instruments was the Rapid Assessment Protocol (RAP), initially developed by the U.S. Environmental Protection Agency (EPA), having as one of the main enthusiasts Hannaford et al., (1997) and, in Brazil, Callisto et al., (2002) in the application impact characterization in parts of hydrographic basins. They adapted the protocol by stipulating scores, observations, and field notes to establish the river condition.

Another widely used technique is the Inverse Distance Weighted (IDW), due to the possibility of evaluating and mapping water quality as mentioned by Mirzaei and Sakizadeh (2016). Gong et al., (2014); Kamaruddin et al., (2021) and Khouni et al., (2021) evaluate that IDW is a more accurate method when compared to Kriging and it adapts well and can be used to manage, through isothermal maps, the location of probable environmental impact events as a guideline for the

implementation of adequate sustainability monitoring and management of the environment.

Given the above, the research proposes to classify the environmental impact in the micro-watershed of the Ouricuri River, integrating physicochemical results, RAP, and IDW interpolation maps as instruments for evaluating environmental impacts in micro-watersheds.

## Material and Methods

### Study area

The study was carried out in the Ouricuri river hydrographic micro-watershed, located in the municipality of Capanema, Pará. The municipality, located in the mesoregion of northeastern Pará and the microregion Bragantina, has a low-density drainage network, mainly formed by creeks, belonging to the basins of Quatipuru, Ouricuri, and Jaburu rivers (Costa et al., 2021). The Ouricuri river is 15 km long, of which 7 km cross the city of Capanema. This river stands out for serving a large portion of the population as to water supply, irrigation of small-scale agricultural activities, and fish farming activities throughout its extension.

Disorderly and continuous expansion in urbanized areas, without any planning, brings a series of environmental and social problems. The municipality of Capanema stands out negatively in this condition as it presents a completely disordered urbanization process, with numerous flaws in the hydro-sanitary network and the collection and disposal of solid waste. In addition, the Ouricuri River currently receives all the city's sewage drainage without any prior treatment. The city involved the river in such a way that currently the riparian vegetation has been replaced by civil and commercial constructions along with its urban extension, as mentioned by Silva et al., (2017). Authors such as Howladar et al., (2020), in their study in the district of Sylhet in Bangladesh, which presents a condition similar to that existing in the municipality of Capanema, reported that the main factor for environmental impacts in urban environments is due to urban infrastructure.

### Sampling and Collection

To collect information on the micro-watershed and its tributaries characteristics, 16 sampling points were selected based on demographic density maps of the municipality, which were subsequently identified *in loco* and georeferenced (Figure 1).

It is worth noting that the sampling points were grouped into categories to identify direct and indirect influences on the Ouricuri River micro-watershed, given that the municipality uses the

river and streams as a drainage network for rainwater and sewage. Given the above, the grouping has the following order: Ouricuri river is formed by points P2, P3, P4, P5, P7, and P8;

tributaries formed by points P9, P10, P11, P12, P13, P14, P15, and P16, and the river source has the code P1.

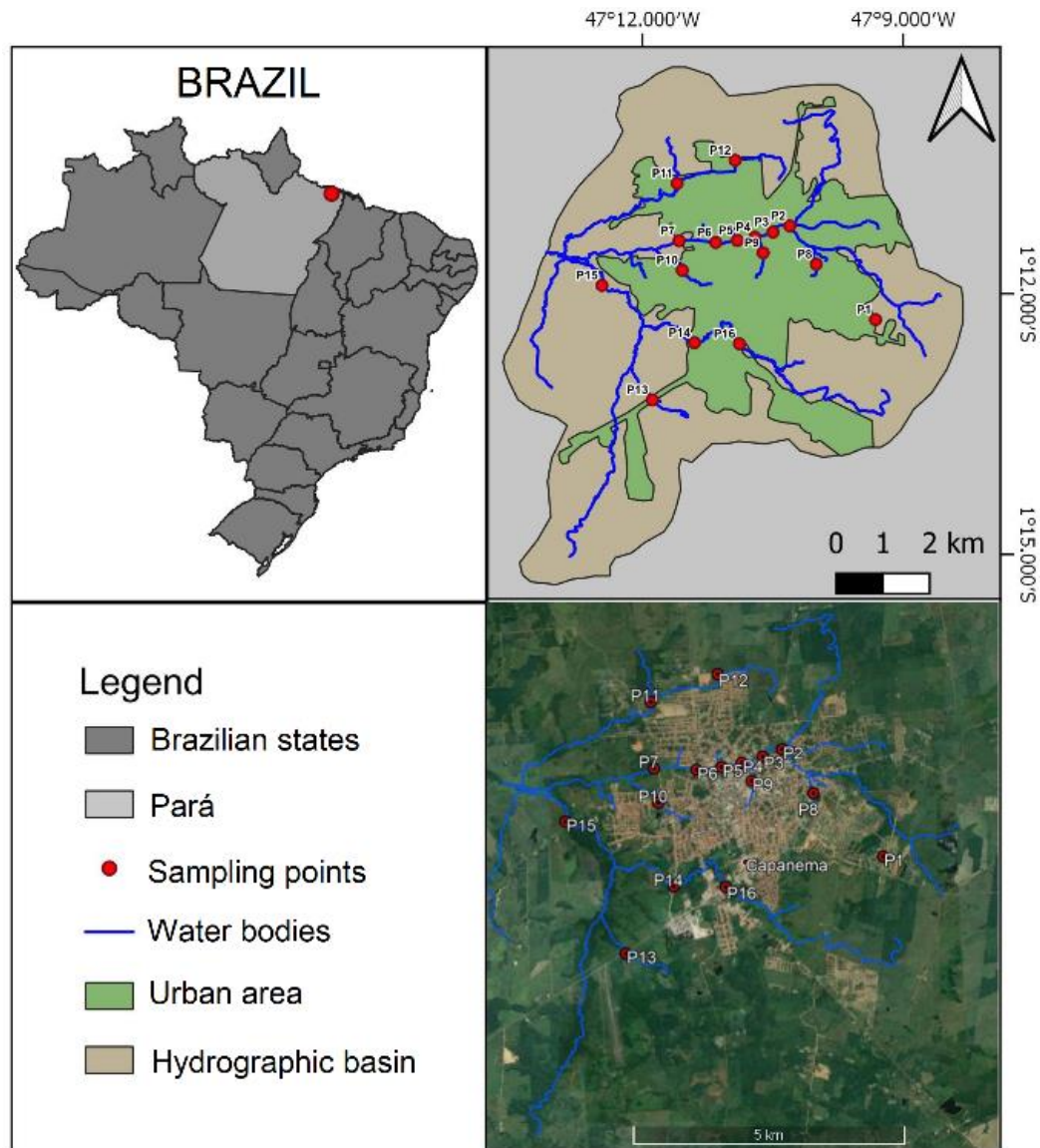


Figure 1. Location of the study area.

The campaigns took place quarterly during 2018, to cover the Amazon seasonality. In each campaign, physical-chemical data and information were collected through the application of the Rapid Protocol for Environmental Assessment (RPEA).

### Physical-chemical analysis

The quantification of dissolved oxygen (DO) was performed in the field, using a multiparameter probe (HI98194, Hanna, George Washington n°270, Smithfield, USA) previously calibrated according to the methodology indicated by the manufacturer. Authors such as Marques et

al., (2020); Diamond et al., (2021); Lee and Shin (2021) and Mainali and Tare (2021), mention the importance of this parameter in studies with this focus and highlight that it becomes a preponderant factor in the characterization of possible environmental impacts.

### Rapid Protocol for Environmental Assessment (RPEA)

To implement the RPEA, a questionnaire with information based on and adapted from protocols developed by Hannaford et al., (1997) and Callisto et al., (2002) was employed. The

following variables were analyzed: water transparency, sediments in the riverbed, percentage of occupation on the banks, presence of residues (garbage), construction on the banks, oils and greases, and presence of animals.

The categories of each variable were ranked, based on the adapted matrix by Leopold et al., (1971) and Callisto et al., (2002) in which activities of lesser impact have lower values. Thus, each category was valued and classified according to the impact it represents, as follows: value 0 for categories that do not indicate an impact on the area; value 1 for moderate-impact categories; and value 2 for high-impact categories (Table 1).

The classification of categories presented in Table 1 was used to quantify the impact on each point by ranking. With this, the sum of the values for each point was carried out and the result indicates the impact evidenced in each point. To standardize the classification, the following ranking was adopted: 0 points with no impact; between 1 and 6 low-impact points; between 7 and 12 moderate-impact points; between 13 and 18 high-impact points; and between 19 and 24 very-high-impact points.

Table 1. Description of variables, their categories, and the class belonging to each impact.

| Variables                                    | Categories                                                                        | Class |
|----------------------------------------------|-----------------------------------------------------------------------------------|-------|
| Water transparency                           | Visibility over 1 m                                                               | 0     |
|                                              | Visibility between 50 cm to 1 m                                                   | 1     |
|                                              | Visibility of a few centimeters below the surface                                 | 2     |
| Sediments at the bottom                      | No mud accumulation is observed                                                   | 0     |
|                                              | There is a small amount of mud present                                            | 1     |
|                                              | The river bottom has a lot of mud, branches, rocks, and garbage                   | 2     |
| Presence of vegetation on the banks          | There are plants on both sides of the river                                       | 0     |
|                                              | Includes pasture and cropping areas                                               | 1     |
|                                              | There are residences, businesses, and industries                                  | 2     |
| Floating or accumulated garbage on the banks | None                                                                              | 0     |
|                                              | Little or just trees, leaves, and water hyacinth                                  | 1     |
|                                              | Lots of garbage (plastics, papers, woods, organic, etc.)                          | 2     |
| Construction on the riverbanks               | No constructions (natural state)                                                  | 0     |
|                                              | Partial presence of construction on the banks (one of the banks)                  | 1     |
|                                              | Large presence of construction (both sides).                                      | 2     |
| Effluent visualization                       | The presence of domestic and industrial effluents is not observed (natural state) | 0     |
|                                              | There are effluents in parts of the river                                         | 1     |
|                                              | Large amount of effluent along the river                                          | 2     |
| Presence of animals                          | Large numbers of fish, amphibians, or aquatic insects                             | 0     |
|                                              | Small quantities of fish, amphibians, or aquatic insects                          | 1     |
|                                              | Not observed                                                                      | 2     |
| Oils and greases                             | Absent                                                                            | 0     |
|                                              | Sparse plumes                                                                     | 1     |
|                                              | High quantity                                                                     | 2     |

Zero value: low or no impact; Value 2: High impact. Source: adapted from Leopold et al., (1971) and Callisto et al., (2002).

#### **Geographical Interpolation System: Inverse Distance Weighted (IDW) method**

To represent the environmental impact on the Capanema hydrographic basin, interpolations were performed with the "IDW Interpolation" tool of the Quantum GIS 3.14.16 software. IDW interpolation (Inverse Distance Weighted

interpolation) proposes that the value of a non-sampled point can be approximated employing a weighted average of values in points within a defined distance or the number of closest points, using a parameter "*p*" (Mitas and Mitasova, 2005). These authors emphasize that the adoption of a "*p*" value equal to 2 is commonly used and recommended in research of this nature.

### **Data Analysis and Interpretation**

Interpolations were performed for each variable on the environmental analysis sheet, according to the classification of each category, as well as for the observed values of dissolved oxygen and the total impact of each point. This analysis enabled us to identify areas of the basin with the greatest impact, and which deserve greater attention. Thus, the interpolation maps represent, through color gradients, the areas where the impact is more latent.

Regarding the results of the instrumental analysis, the values were statistically treated to eliminate systematic and random errors, for this, tests of data normalization were applied, in addition to the standard deviation and coefficient of variation tests to ensure the precision and accuracy of the results, as suggested by Hernandez et al., (2020).

### **Results and Discussion**

#### ***Rapid Protocol for Environmental Assessment (RPEA)***

Regarding the results obtained by applying the RPEA (Table 2), the main considerations were: there is little visibility below the river surface in 43.75% of the points, being the water transparency restricted to a few centimeters. Smaller transparencies may indicate the presence of higher concentrations of organic elements, suspended matter, and nutrients (Ma et al., 2015). Furthermore, it was noted that the low visibility is probably related to the strong influence of urban effluents connected to the river.

In most of the analyzed points, the presence of bottom sediments was detected in little (43.75%) and much quantity (25%). According to Reis (2017) and Bassooma et al., (2021), sediments can move and accumulate different substances, which is why some are considered to be difficult to degrade, making benthic habitats a source of secondary contamination in the ecosystem. Thus, most of the places that presented sediments at the bottom of the river are found in areas with greater population and structural density.

There is vegetation at various points along the river, however, part of this vegetation is not characterized as riparian forest. Thus, although it is shown in Table 2 that the micro-watershed is included in class 0, the river is still threatened by the absence of its native vegetation at many points along its path.

Similarly, despite the occurrence of little solid waste in most of the areas analyzed, there is a

very high amount of plastic and organic waste in the most central regions of the municipality, where there is commercial activity and domestic residences in the vicinity of Ouricuri. Thus, waste discarded in rivers can affect aquatic biodiversity and consequently health risks (Meenal et al., 2021).

There are several constructions on the banks of the river due to the lack of urban planning and organization. The excess of buildings close to the river can impact water quality through degradation, deforestation, morphological changes, and the disappearance of canals (Paiva et al., 2020). Irregular occupation of these areas occurs in several points of the studied area, mainly in places where the commercial center of the municipality is located.

As for the release of effluents, it was noted that in 80% of the points there are punctual and diffuse sources of effluent, whether constant or seasonal, released directly into the river or indirectly through the connected channels called tributaries. According to Peters et al., (2019), studying the rural area of Beijing, rapid urban development leads to a decline in water quality due to the presence of effluents in the water body. When comparing the situation described by the authors with the situation object of the present study, similarities are identified regarding the presence of constructions on the banks of the river along with its urban extension, which is likely responsible for the effluents released into the river.

In 62.50% of the points, few or no animals were observed in the waters of the micro-watershed. This condition of degradation of urban rivers causes the disappearance of several species of animals, according to Barreto et al., (2020). Similarly, the loss of aquatic biodiversity may be related to the growing urbanization of Capanema.

In 56.25 % of the sampling points, the presence of oils and greases in surface water was observed. The large volume of waste oils, especially when incorrectly discarded in rivers, contaminate the aquatic environment in various ways, affecting the concentration of DO, foaming, releasing offensive odors, and altering the balance of the ecosystem (Awogbemi and Panda, 2021). The occurrence of these products being launched in Ouricuri is observed more frequently in the municipality commercial center, due to the presence of motorcycle and vehicle workshops that do not comply with environmental legislation and dispose of oil and degreasers directly into the surface drainage network.

Table 2. Frequency of environmental impact classification in the Ouricuri river basin.

| Variável                                     | Categorias                                                                        | Classe | Porc. (%) |
|----------------------------------------------|-----------------------------------------------------------------------------------|--------|-----------|
| Water transparency                           | Visibility over 1 m                                                               | 0      | 25.00     |
|                                              | Visibility between 50 cm to 1 m                                                   | 1      | 31.25     |
|                                              | Visibility of a few centimeters below surface                                     | 2      | 43.75     |
| Sediments at the bottom                      | No mud accumulation is observed                                                   | 0      | 31.25     |
|                                              | There is a small amount of mud present                                            | 1      | 43.75     |
|                                              | The river bottom has a lot of mud, branches, rocks, and garbage                   | 2      | 25.00     |
| Presence of vegetation on the banks          | There are plants on both sides of the river                                       | 0      | 62.50     |
|                                              | Includes pasture and cropping areas                                               | 1      | 12.50     |
|                                              | There are residences, businesses, and industries                                  | 2      | 25.00     |
| Floating or accumulated garbage on the banks | None                                                                              | 0      | 25.00     |
|                                              | Little or just trees, leaves, and water hyacinth                                  | 1      | 43.75     |
|                                              | Lots of garbage (plastics, papers, woods, organic, etc.)                          | 2      | 31.25     |
| Construction on the riverbanks               | No constructions (natural state)                                                  | 0      | 12.50     |
|                                              | Partial presence of construction on the banks (one of the banks)                  | 1      | 68.75     |
|                                              | Large presence of construction (both sides).                                      | 2      | 18.75     |
| Effluent visualization                       | The presence of domestic and industrial effluents is not observed (natural state) | 0      | 43.75     |
|                                              | There are effluents in parts of the river                                         | 1      | 43.75     |
|                                              | Large amount of effluent along the river                                          | 2      | 12.50     |
| Presence of animals                          | Large numbers of fish, amphibians, or aquatic insects                             | 0      | 37.50     |
|                                              | Small quantities of fish, amphibians, or aquatic insects                          | 1      | 31.25     |
|                                              | Not observed                                                                      | 2      | 31.25     |
| Oils and greases                             | Absent                                                                            | 0      | 43.75     |
|                                              | Sparse plumes                                                                     | 1      | 43.75     |
|                                              | High quantity                                                                     | 2      | 12.50     |

Source: adapted from Leopold et al., (1971) and Callisto et al., (2002).

### **Dissolved oxygen (DO)**

The dissolved oxygen presented minimum and maximum values equal to 1.38 mg L<sup>-1</sup> and 5.81 mg L<sup>-1</sup>, respectively, with an average of around 4.40 mg L<sup>-1</sup>, standard deviation (SD) equal to 0.34, and coefficient of variation (CV) of 7.72%. The statistical interpretation of the DO results allows us to state that the sampling presented a homogeneous

behavior (CV < 35%), although the amplitude of the results is relatively large.

The CONAMA resolution 357/2005 guides on the classification and purpose of water bodies, according to their predominant uses, and for the discharge of effluents. To assess the quality of surface freshwaters for consultative or non-consultative use, the legislation suggests that the DO content should be above 5 mg L<sup>-1</sup> and class 2



for waters that have not yet been evaluated by the regional river basin committees or location.

As it is a sensitive matrix to natural or anthropogenic storms, authors such as Diamond et al., (2021) assess these variations as normal, however, they advise that the origin of the interferences be analyzed to identify possible agents.

Based on this information, the explanation for these values below established standards is directed towards the direct influence of irregular constructions on the banks of the river, lack of a sewage treatment system, and incorrect disposal of solid waste, with the final destination being the micro-basin. The section that suffers the most is in the central area of the municipality, where the longest extension of the Ouricuri River runs through because as stated by Chakravarty and Gupta (2021) and Lee and Shin (2021), there is a significant reduction in the concentration of DO in areas with the discharge of sewage with a high concentration of organic matter.

### IDW interpolation versus RPEA

By categorizing the variables described in the RPEA, it was possible to determine the impact gradient of the researched area and, consequently, the implementation of intensity maps based on the responses obtained.

The mosaic of information presented in Table 2 illustrates the sampling points, through color gradients, with a greater probability of environmental impact, enabling better management and decision-making in favor of remediation actions.

Regarding the maps from the IDW (Figure 2), interpolation A, which refers to water transparency, presented points P2, P3, P4, P8, P9, P11, and P18 as being category 2, which is related to the greatest impact. This condition is associated with the RPEA results, in which diffuse effluent sources are observed carrying a large amount of particulate material, including waste from domestic sewage and cesspools with direct connection to the river and tributaries.

Interpolation B refers to bottom sediments, with P1, P7, P12 as the most impacted points. P1 is the river source that presents a large number of sediments from the deposition of leaves and branches, as it is located inside the virgin forest. The other points are in places without the presence of riparian vegetation, in both P7 (Ouricuri river) and P12 (tributary). The inexistence of this natural barrier allows the transport of all types of sediment, including solid waste to the micro-watershed bed

and its tributaries, as emphasized by Bassooma et al., (2021).

As for the occupation of the banks, interpolation C, the points with the greatest impact are P3, P4, P5, and P8, all located along the Ouricuri River. These places stood out for being inserted in the commercial center of Capanema, where the buildings replaced the riparian vegetation, such as the municipal market, motorcycle workshops, supermarkets, shops, bars, and restaurants that contribute to the degradation of native vegetation and water quality, as cited by Costa et al., (2021).

Interpolation D refers to the presence of garbage in the river. The points P3, P4, P5, P7, P9, and P10 presented the greatest impact. This fact coincides with the previous interpolation, as these points are in the commercial area of the municipality, whose main factor is the disposal of solid waste in the river and the carrying of large amounts of particulate materials and sediments through the river drainage system that acts as a sanitary sewage system, significantly impacting the fauna and water quality of the Ouricuri micro-watershed, as mentioned by Silva et al., (2016).

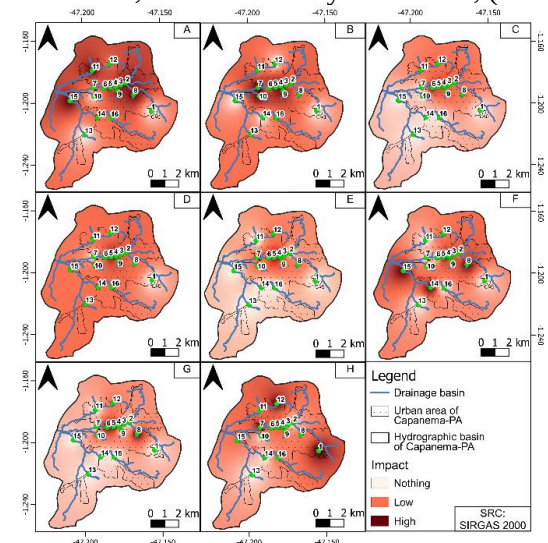


Figure 2. Data interpolation map for the analyzed variables in the Capanema hydrographic basin, Pará, in which: A. Water transparency; B. Bottom sediments; C. Occupation of riverbanks; D. presence of garbage; E. Changes in river banks; F. Presence of effluents; G. Oils and greases; H. Presence of animals.

Regarding the interpolations E and F, which points P4 and P5 stand out, the conditions are similar as the sampling points are located in the commercial area that presents numerous infrastructure problems concerning solid waste and sanitary sewage, in addition to suppression of riparian vegetation by aesthetic works without environmental responsibility.

The interpolation G, referring to oils and greases, has a moderate impact assessment, mainly at points associated with the Ouricuri River. This moderate condition is characterized by the presence of numerous motorcycle workshops, restaurants, and bars that use the public drainage system to discharge effluents and, therefore, the insertion of these organic compounds into the water body, harming the ecosystem.

As for the presence of animals (interpolation H), the most impacted points are P4, P5, P8, P9, P14, and P15. Silva et al., (2016) and Costa et al., (2021) report that the main conditioning factor for fauna diversity is associated with water quality, as the highlighted points are in the region with the greatest structural and environmental problems, these results are justified. Points 14 and 15 refer to tributaries whose main conditioning factor is the presence of domestic effluents from homes located in the vicinity and narrowing and silting of the channel, which impairs the oxygenation of the water body, as suggested by Barreto et al., (2020) and Awogbemi and Panda (2021).

### IDW Interpolation versus Dissolved Oxygen Concentration

The most impacted sections are at points P8, P9, and P10, as they present DO contents 60% below the value established by CONAMA legislation (Figure 3). Being tributaries, the similarity between the points is due to narrowing and silting by the presence of residential buildings, and with a small water flow. Silva et al., (2016) and Costa et al., (2021) state that these places, formerly natural streams, became a deposit of diffuse effluents and the excess of organic matter ends up changing the environmental condition to the point of being characterized as an anoxic environment in some parts.

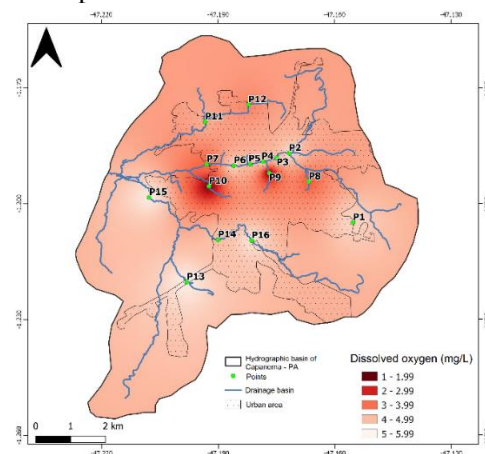


Figure 3. Interpolation of dissolved oxygen (mg. L<sup>-1</sup>) in the Capanema-PA hydrological basin.

The other points, although did not present high-impact conditions, also represent moderate impact given that the average value of DO is below 5 mg L<sup>-1</sup>.

According to Smith et al., (2018), benthic biodiversity is strongly related to water quality, so that the degradation of quality implies impacts on the aquatic environment, causing great loss in the ecosystem. The composition of the ichthyofauna can also be impacted by human activities, which result in pollution, siltation, and the removal of riparian vegetation.

### Total Impact on Points (TIP)

Figure 4 shows the correlation between the information obtained from the RPEA evaluation and the DO content analysis, presenting as a product an interpolation to predict the total impact of the studied region.

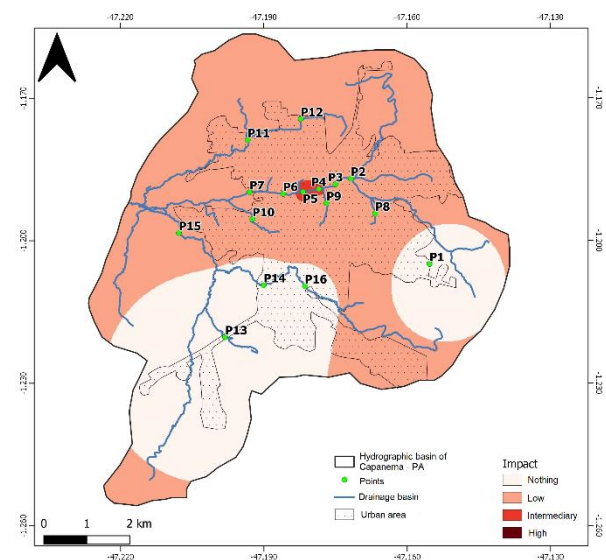


Figure 4 - Environmental impact on the microbasin of the Ouricuri River in Capanema.

From this perspective, it was found that the high-impact sections are associated with points P4, P5, and P6, and moderate-impact with P2, P3, P7, P8, P9, P10, P11, P12, and P15. The main characteristic of the impacted areas is a direct action on the Ouricuri River, showing urbanization as a protagonist in the degradation of water resources, mainly due to the disorderly occupation around the river and its tributaries, releasing diffuse effluents, solid waste, oils, and other sources of contamination that harm the ecosystem and the use of water (Paiva et al., 2020).

As for the other highlighted areas, the concern is similar since the standard discharge of effluents, solid residues, suppression of riparian vegetation, and constructions in Permanent Protection Areas (APP's) are commonly practiced. Such actions directly reflect the loss of biodiversity



and the increase of harmful organisms to human health (Agostinho et al., 2005; Wear et al., 2021). Urban planning is needed to minimize the current impacts on the Ouricuri micro-basin. In addition, government actions are needed to adapt the National Solid Waste Policy (PNRS) and the National Basic Sanitation Plan (PNSB), which are government instruments aligned with environmental preservation and health guarantee.

Interactions between anthropic and natural environments must also be considered and encouraged for the recovery of water bodies so that the natural conditions of water resources are valued. In addition, the community must reject urban environmental degradation and work together to restore natural environments as addressed by Hawkins et al., (2020).

## Conclusions

The association of methodologies such as RPEA and IDW Interpolation enable to verify that the Ouricuri microbasin region presents serious environmental problems, as moderate to high impact was detected on the studied water bodies. The main indicators of this problem come mainly from the direct discharge of diffuse effluents both in the Ouricuri River and its tributaries, and the destruction of riparian vegetation by constructions along with the protected areas, causing in several points an anoxic condition and exponential loss of local biodiversity.

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