

Universidade do Estado do Pará
Pró-Reitoria de Pesquisa e Pós-Graduação
Centro de Ciências Naturais e Tecnologia
Programa de Pós-Graduação em Ciências Ambientais
Doutorado Acadêmico



ANTÔNIO PEREIRA JÚNIOR

**QUALIDADE DA ÁGUA E AS PRESSÕES ANTRÓPICAS
EM AMBIENTES URBANOS AMAZÔNICOS: O CASO DO
IGARAPÉ PARAGOMINAS (PA)**

Belém
2025

ANTÔNIO PEREIRA JÚNIOR

**QUALIDADE DA ÁGUA E AS PRESSÕES ANTRÓPICAS EM
AMBIENTES URBANOS AMAZÔNICOS: O CASO DO IGARAPÉ
PARAGOMINAS (PA)**

Tese apresentada como requisito parcial para obtenção do título de Doutor em Ciências Ambientais no Programa de Pós-Graduação em Ciências Ambientais.
Universidade do Estado do Pará.

Orientador: Professor Dr. Gundisalvo Piratoba Morales.

Co-Orientador: Professora Dr. Norma Ely Santos Beltrão

Belém
2025

Dados Internacionais de Catalogação na Publicação (CIP),
Biblioteca do Centro de Ciências Naturais e Tecnologia, UEPA, Belém - PA.

P436q Pereira Júnior, Antônio

Qualidade da água e as pressões antrópicas em ambientes urbanos amazônicos: o caso do Igarapé Paragominas (PA). / Antônio Pereira Júnior; Orientador Gundisalvo Piratoba Morales; Coorientadora Norma Ely Santos Beltrão. -- Belém, 2025.

148 f. : il. ; 30 cm

Tese (Doutorado em Ciências Ambientais) - Universidade do Estado do Pará, Centro de Ciências Naturais e Tecnologia, Belém, 2025.

1. Água - Qualidade - Paragominas (PA). 2. Natureza - Influência do homem - Paragominas (PA). 3. Impacto Ambiental - Paragominas (PA). 4. Desmatamento - Paragominas (PA). I. Morales, Gundisalvo Piratoba. II. Beltrão, Norma Ely Santos. III. Título.

CDD 628.16


ANTÔNIO PEREIRA JÚNIOR

**QUALIDADE DA ÁGUA E AS PRESSÕES ANTRÓPICAS EM
AMBIENTES URBANOS AMAZÔNICOS: O CASO DO IGARAPÉ
PARAGOMINAS (PA)**

Tese apresentada como requisito parcial para obtenção do título de Doutor em Ciências Ambientais no Programa de Pós-Graduação em Ciências Ambientais. Universidade do Estado do Pará.

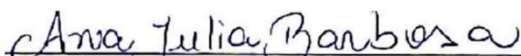
Data da aprovação: 30/05/2025.

Banca Examinadora

 Documento assinado digitalmente
GUNDISALVO PIRATOBA MORALES
Data: 30/05/2025 23:09:39-0300
Verifique em <https://validar.iti.gov.br>


– Orientador

Prof (a). Gundisalvo Piratoba Morales
Doutor em Ciências Geoquímicas e Petrologia
Universidade do Estado do Pará




– 1º Examinadora

Profª. Ana Júlia Soares da Silva Barbosa
Doutor em Recursos Naturais da
Amazônia Universidade do Estado do
Pará

 Documento assinado digitalmente
EDMIR DOS SANTOS JESUS
Data: 31/05/2025 09:37:27-0300
Verifique em <https://validar.iti.gov.br>


– 2º Examinador

Professor Edmir dos Santos Jesus
Doutor(a) em Ciências Climáticas
Instituto Tecnológico da Vale

 Documento assinado digitalmente
HEBE MORGANNE CAMPOS RIBEIRO
Data: 31/05/2025 08:47:56-0300
Verifique em <https://validar.iti.gov.br>

– 3º Examinadora

Profª. Hebe Morgane Campos Ribeiro
Doutor em Engenharia Elétrica
Universidade do Estado do Pará

 Documento assinado digitalmente
LUCY ANNE CARDOSO LOBÃO GUTIERREZ
Data: 30/05/2025 11:58:55-0300
Verifique em <https://validar.iti.gov.br>

– 4º Examinadora

Profª. Lucy Anne Lobão Gutierrez
Doutor em Geologia e Geoquímica
Universidade do Estado do Pará

Aos meus pais, *in memoriam*, e familiares em todos os níveis consanguíneos, pelo apoio durante todos os anos de minha carreira acadêmica e, em especial, no decorrer do curso de Graduação.

Quando lhe disserem “**não**”, não retruque!
Trabalhe! Honre sua postura! Lute! Não se
queixe! Vença! Depois disto tudo, deixe
que as pessoas o julguem!

Eu

O caminho até o topo do monte pode ser
desgastante, demorado, arriscado, difícil e,
em alguns momentos, aterrorizador. No
entanto, vou te pedir uma coisa do fundo
do meu coração: não vá desistir agora.
Carregue só o que importa, nada de pesos
desnecessários. Tenha fé em **DEUS** e
confiança em si mesmo. [...] Quando você
chegar lá em cima, você descobrirá que a
graça de tudo estava nas histórias que
você viveu, nas pessoas que você
conheceu, nos tombos que levou, nos
desafios que enfrentou e em tudo o que
você descobriu sobre si mesmo ao longo
da jornada. É na travessia que a mágica
acontece!

Autor desconhecido

QUALIDADE DA ÁGUA E AS PRESSÕES ANTRÓPICAS EM AMBIENTES URBANOS AMAZÔNICOS: O CASO DO IGARAPÉ PARAGOMINAS (PA)

RESUMO

Os problemas ambientais enfrentados pelos municípios brasileiros frequentemente envolvem processos de desmatamento, alterações nos aspectos ambientais e degradação da qualidade da água. No entanto, nem todos os 5.570 municípios do país dispõem de dados sistematizados sobre essas questões. Essa lacuna foi identificada no município de Paragominas (PA), o que motivou a realização desta pesquisa, cujo objetivo foi analisar as relações entre o desmatamento, os aspectos ambientais e a qualidade da água no trecho urbano do igarapé Paragominas. A abordagem metodológica adotada foi investigativa, com natureza observacional e caráter quantitativo. O trecho analisado atravessa a zona urbana e foi dividido aleatoriamente em cinco áreas, organizadas do ponto menos urbanizado ao mais urbanizado, seguindo o sentido montante-jusante. Os resultados indicaram que o desmatamento foi impulsionado pela expansão da agricultura (de 1.342 ha para 103.164 ha) e da área urbana (de 1.331,5 ha para 2.026,8 ha), resultando na perda de 207,9 ha de superfície hídrica. Essas transformações contribuíram para a degradação da integridade do habitat aquático. A análise dos dados obtidos permitiu caracterizar os estados ambientais das cinco áreas amostradas, evidenciando impactos significativos decorrentes da pressão antrópica sobre o sistema hídrico urbano. **A₁: Rodovia Constantino Pereira do Sacramento**, com substituição da mata ciliar por vegetação arbustiva e herbácea o que decretou valores elevados para os impactos antropogênicos - IA ($\Sigma = 55$) e para a condição ambiental - CA ($\Sigma = 46$), logo, o valor do índice de Integridade do Habitat (IIH = 47,2%), permitiu a classificação desta área como “área impactada”, devido as alterações na extensão - E (largura - L, 97 ± 49.1 m; comprimento - C = 95.7 ± 4.0 m; profundidade - P = 1.8 ± 0.3 m), o que alterou a qualidade da água - QA ($T^{\circ}\text{C} = 32.2 \pm 2.2$ °C; OD = 2.0 ± 1.1 mg/L; $\text{NH}_3 = 0.13$ mg/L); Na **A₂: Avenida Selecta**, IA ($\Sigma = 31$); CA ($\Sigma = 29$), indicaram um IIH baixo (= 28.6%), logo, “área altamente impactada”, E (L = 73 ± 38.0 m; C = 47.3 ± 9.5 m; P = 1.1 ± 0.3 m); QA ($T^{\circ}\text{C} = 32.6 \pm 2.1$ °C; OD = 2.3 ± 0.8 mg/L; $\text{NH}_3 = 0,26$ mg/L); Em **A₃: confluência da rua Gregório Santos Araujo com PA 125**, IA ($\Sigma = 24$); CA ($\Sigma = 24$); IIH (= 7.8%), ou seja, “área altamente impactada”, QA ($T^{\circ}\text{C} = 31.5 \pm 1.0$; OD = 1.7 ± 0.4 mg/L; $\text{NH}_3 = 0.37$ mg/L); **A₄ – Lago Verde**, o IA ($\Sigma = 10$), CA ($\Sigma = 3$), IIH (4.2), “área altamente impactada”; E (L = 100.0 ± 50 m; C = 34.0 ± 9.2 m; P = 2.0 ± 0.6 m); QA ($T^{\circ}\text{C} = 37.8 \pm 2,6$; OD = 0.9 ± 0.2 mg/L; $\text{NH}_3 = 0.81$ mg/L); **A₅ – Rua Padre Carvalho**: IA ($\Sigma = 36$); CA ($\Sigma = 37$); IIH (10.4) “área altamente impactada”; QA ($T^{\circ}\text{C} = 32.2 \pm 1.0$; OD = 1.2 ± 0.9 mg/L; $\text{NH}_3 = 1.21$ mg/L). Logo, o trecho urbano do igarapé Paragominas, após a urbanização sofre impactos antropogênicos que alteram as condições ambientais do habitat aquático e está interferindo da perda gradual da qualidade da água.

Palavras-chave: Impactos antropogênicos; índice de Integridade do Habitat; Urbanização.

WATER QUALITY AND ANTHROPOGENIC PRESSURES IN AMAZONIAN URBAN ENVIRONMENTS: THE CASE OF THE IGARAPÉ PARAGOMINAS (PA)

ABSTRACT

The environmental problems faced by Brazilian municipalities often involve deforestation processes, changes in environmental aspects and degradation of water quality. However, not all of the country's 5,570 municipalities have systematized data on these issues. This gap was identified in the municipality of Paragominas (PA), which motivated the realization of this research, whose objective was to analyze the relationships between deforestation, environmental aspects, and water quality in the urban stretch of the Paragominas stream. The methodological approach adopted was investigative, observational in nature and quantitative-qualitative. The analyzed stretch crosses the urban zone and was randomly divided into five areas, organized from the least urbanized to the most urbanized point, following the upstream-downstream direction. The results indicated that deforestation was driven by the expansion of agriculture (from 1,342 ha to 103,164 ha) and urban area (from 1,331.5 ha to 2,026.8 ha), resulting in the loss of 207.9 ha of water surface. These transformations contributed to the degradation of the integrity of aquatic habitat. The analysis of the data obtained allowed us to characterize the environmental states of the five sampled areas, evidencing significant impacts resulting from anthropogenic pressure on the urban water system. **A1: Constantino Pereira do Sacramento Highway**, with replacement of riparian forest by shrub and herbaceous vegetation, which decreed high values for anthropogenic impacts - IA ($\Sigma = 55$) and for environmental condition - CA ($\Sigma = 46$), therefore, the value of the Habitat Integrity index was also high (IIH = 47.2%), therefore "impacted area", due to changes in extension - E (width - L, 97 ± 49.1 m; length - C = 95.7 ± 4.0 m; depth - P = 1.8 ± 0.3 m), which altered the water quality - QA (T °C = 32.2 ± 2.2 °C; DO = 2.0 ± 1.1 mg/L; NH₃ = 0.13 mg/L); On the **A2: Avenida Selecta**, IA ($\Sigma = 31$); CA ($\Sigma = 29$), indicated a low IIH (= 28.6%), therefore, "highly impacted area", E (L = 73 ± 38.0 m; C = 47.3 ± 9.5 m; P = 1.1 ± 0.3 m); QA (T°C = 32.6 ± 2.1 °C; DO = 2.3 ± 0.8 mg/L; NH₃ = 0.26 mg/L); In **A3: confluence of Gregório Santos Araujo Street with PA 125**, IA ($\Sigma = 24$); CA ($\Sigma = 24$); IIH (= 7.8%), i.e. "highly impacted area", QA (T.°C = $3.1.5 \pm 1.0$; DO = 1.7 ± 0.4 mg/L; NH₃ = 0.37 mg/L); **A4 – Lago Verde**, the IA ($\Sigma = 10$), CA ($\Sigma = 3$), IIH (4.2), highly impacted area"; E (L = 100.0 ± 50 m; C = 34.0 ± 9.2 m; P = 2.0 ± 0.6 m); QA (T°C = 37.8 ± 2.6 ; DO = 0.9 ± 0.2 mg/L; NH₃ = 0.81 mg/L); **A5 – Padre Carvalho Street**: IA ($\Sigma = 36$); CA ($\Sigma = 37$); IIH (10.4) "highly impacted area"; QA (T°C = 32.2 ± 1.0 ; DO = 1.2 ± 0.9 mg/L; NH₃ = 1.21 mg/L). Therefore, the urban stretch of the Paragominas stream, after urbanization, suffers anthropogenic impacts that alter the environmental conditions of the aquatic habitat and is interfering with the gradual loss of water quality.

Keywords: Anthropogenic impacts; Habitat Integrity Index; Urbanization.

SUMÁRIO

1	INTRODUÇÃO (GERAL)	11
1.2	REFERÊNCIAS DA INTRODUÇÃO (GERAL)	15
2	ARTIGO 1	
	Geospatial analysis of deforestation, land use and impacts of water resources in Paragominas, Pará	22
	RESUMO	22
	ABSTRACT	22
1	INTRODUCTION	23
2	MATERIAL AND METHODS	25
3	RESULTS	27
4	DISCUSSIONS	34
5	CONCLUSIONS	38
	REFERÊNCIAS	38
	ARTIGO 2	
	Environmental integrity in two areas of the Paragominas stream in the municipality of the same name, Pará, Brazil	47
	RESUMO	47
	ABSTRACT	47
	RESUMEN	48
1	INTRODUCTION	48
2	MATERIAL AND METHODS	49
3	RESULTS	54
4	DISCUSSIONS	58
5	CONCLUSIONS	61
	REFERENCES	62
	Artigo 3	
	Analysis of three urban areas of the Paragominas creek regarding environmental integrity, in the homonymous municipality, Pará, Brazil.	
	ABSTRACT	65
	RESUMO	65
	RESUMEN	65
1	INTRODUCTION	66
2	MATERIAL AND METHODS	67

3	RESULTS	74
4	DISCUSSIONS	86
5	CONCLUSIONS	88
	REFERENCES	89

	ARTIGO 4	
	Preliminary analysis of water quality in the urban stretch of Paragominas stream, Pará, Brazil	92
	ABSTRACT	92
	RESUMO	92
	RESUMEN	93
1	INTRODUCTION	93
2	MATERIAL AND METHODS	95
3	RESULTS	101
4	DISCUSSIONS	104
5	CONCLUSIONS	115
	REFERENCES	116
	ARTIGO 5	
	First study of ammonia (NH ₃) contained in the Paragominas stream in the municipality of the same name, southeastern Pará	120
	RESUMO	120
	ABSTRACT	120
1	INTRODUCTION	121
2	MATERIAL AND METHODS	122
3	RESULTS	130
4	DISCUSSIONS	133
5	CONCLUSIONS	138
	REFERENCES	139
	CONCLUSÕES (GERAIS)	145

INTRODUÇÃO GERAL

O progresso socioeconômico que ocorre nos 5.570 municípios brasileiros causa a derrocada da cobertura vegetal, especialmente nas margens dos corpos hídricos que perpassem nas chamadas áreas urbanas (SANTOS; AQUINO; SANT'ANA, 2024; TELES; SANTOS; PINHEIRO, 2022). Estas matas possuem uma grande importância (BRASIL, 2012) para a manutenção da qualidade da água, já que o uso e ocupação do solo é modificado a partir do desenvolvimento de atividades antrópicas (NASCIMENTO, 2001), como cultivos agrícolas, uso de fertilizantes e defensivos agrícolas, além da pecuária (KOHLENER *et al.*, 2021a).

Esta derrocada é denominada de desmatamento que, além da pecuária e agricultura, também envolve a construção de rodovias, mineração e sojicultura que ora encontra-se em plena expansão (BORGES, 2023). Essa relação tem associação ativa tanto com o incremento populacional quanto com o do produto interno bruto (PIB), principalmente pela expansão da pecuária e sojicultura (ALVES, 2021). Mas todo este crescimento econômico deve circular intermunicípios e, para isto, o desmatamento abre caminho para a construção de rodovias (LACERDA, 2024).

Estes desenvolvimentos econômicos, acarretam um crescimento populacional (LI, J., *et al.*, 2023; SANTOS, D.; SANTOS, V., 2021), em face da necessidade de mão-de-obra, o que incrementa e desloca a fronteira urbana dos municípios até as margens dos corpos hídricos que perpassam pela área urbana (PRESTES *et al.*, 2025;), além de elevarem o consumo de água e a geração de efluentes (MEDEIROS; RUFINO; ARAGÃO, 2024) que, em geral, por deficiência do saneamento básico, desaguam nas águas superficiais, e comprometem a qualidade ambiental desse recurso natural (ANH *et al.*, 2023; WERNER, 2025; ZHAO *et al.*, 2021).

O desmatamento nos municípios, em geral, abrange as chamadas bacias hidrográficas – BHs (KOHLENER *et al.*, 2021b) onde a extensão desta ação foi superior a 11.000 ha e, na região Norte, no estado do Pará, a perda desta vegetação foi superior a 20% (RIBEIRO *et al.*, 2022). Como toda causa tem seu efeito, a perda da vegetação em BHs, especialmente na floresta Amazônica e zona ciliar, tem uma resposta negativa porque causa a perda da biodiversidade, tanto de fauna quanto de flora (FAUSTO *et al.*, 2023), que podem ser mensurados por Índices de Integridade do Habitat - IIH (SANTOS, 2019; SANTOS *et al.*, 2021).

A aplicação deste índice se mostra eficiente e eficaz nas avaliações, pesquisas e estudos em bacias hidrográficas (SANTOS; OLIVEIRA; MORTATI, 2017; SILVA *et al.*, 2023), porque as ações antrópicas são fatores intervenientes na qualidade da água apresentam ocorrências globais que comprometem as funções ecossistêmicas destas águas, como a balneabilidade, especialmente em áreas que ainda estão em desenvolvimento econômico, populacional e urbano (CAI *et al.*, 2020; MO *et al.*, 2023; WANG, 2023). O problema é que este nexos, atua sobre a qualidade da água porque o crescimento populacional tem uma ligação direta com o crescimento econômico, ou seja, na formação de uma nova sociedade (ALMEIDA, 2017; Li, X., *et al.*, 2023)

Um dos problemas ambientais mais frequentes a nível global, é a qualidade da água e seus parâmetros (OMER, 2020), especialmente aquelas em perpassam em trechos urbanos (TUNDISI; WENDLAN; MENDIONDO, 2023). Outro problema é a extensão territorial, tanto na dimensão geográfica, crescimento populacional (LOURENÇO *et al.*, 2022), e composição de estudos que tenham gerado dados úteis a uma gestão hídrica e ambiental (EMPINOTTI *et al.*, 2021) em obediência aos quesitos componentes das normativas que contenham diretrizes acerca desta qualidade (ANA, 2021; BRASIL, 2005; 2011).

Nesse ponto, verifica-se que a dificuldade quanto a manutenção e obediência à legislação da qualidade da água de forma direta (BRASIL, 1997; 2005; 2011). Dentre os antrópicos, tem-se a produção de materiais inorgânicos e orgânicos, advindas das excretas humanas e da pecuária, como a uréia (NH_2), que serão decompostos na água e podem gerar substâncias tóxicas como a amônia não ionizada ou livre - NH_3 (BERLANDA *et al.*, 2021; VIEIRA, 2024). Some-se a esses impactos, o desmatamento efetuado as margens dos corpos hídricos, o que permite maior radiação solar e provoca tendência de elevação na temperatura na coluna d'água e isto incrementa a produção desta amônia (FRITZSONS *et al.*, 2004; REIS; MENDONÇA, 2009).

Além desta tendência, há uma instabilidade do talude marginal, que pode gerar erosões e modificar, por deposição sedimentar, o substrato de fundo e, dessa forma, alterar o *habitat* de invertebrados e outras biotas aquáticas, além da perda da profundidade (LIMA, 2021; WASIS; HARLAN; PUTRA, 2020). Esta perda pode causar enchentes, inundações, e elevar o risco de inundações e enxurradas (RAHAMANI *et al.*, 2018). Outro aspecto da ocorrência desta tendência, é a perda da concentração do oxigênio dissolvido – OD (SELIM *et al.*, 2023; ZHANG *et al.*, 2023).

Conseqüentemente, ao reduzir a concentração desse gás, em águas recreacionais e de suporte nutricional (Ex.: ictiofauna), a energia é transferida de forma direta na interface ar-água devido a radiação solar direta neste local, bem como a não há intercepção de nutrientes e de sedimentos (CASATTI, 2010; GODOY; LIMA JÚNIOR, 2022). Não se deve ignorar o lançamento de efluentes domésticos (ALMEIDA JÚNIOR; LEME; GONÇALVES, 2022) e industriais (esgoto bruto) contendo substâncias tóxicas que alteram as condições físico-química das águas superficiais (FRITZSONS *et al.*, 2005; VERAS *et al.*, 2023).

Os problemas descritos até agora são predominantes em todos os municípios brasileiros (FREITAS; PIRES; BENINCÁ, 2024; IBGE, 2023; TORDIN, 2025), e isto abrange os 144 municípios paraenses (MOREIRA FILHO; BRELAZ, 2022; PICANÇO *et al.*, 2022) com destaque para Paragominas, localizado no sudeste do estado do Pará. Nele, também há deficiência na coleta, destinação e disposição final dos resíduos sólidos domésticos, as embalagens plásticas como as garrafas de Politereftalato de etileno – PET (CHAMORRO, 2021; JONES, 2022), que podem causar poluição na água quando assumir a forma de microplásticos, cujas partículas são menores que 5mm (DAR, *et al.* 2025; QUEIROZ, 2022; MONTAGNER *et al.*, 2021), que atingem, de forma direta, a biota aquática sejam invertebrados ou vertebrados (RAMLEE *et al.*, 2025).

No município de Paragominas, a microbacia do rio principal, o Uraim, tem tributários de margem esquerda e direita como os igarapés 54 (GALVÃO, 2020; VENTURIERI *et al.* 2005), sete (GAMA *et al.*, 2006), Maritaca ou Piriazinho, e os rios Escadinha e Água Suja (PARAGOMINAS, 2020), além do igarapé Paragominas (RODRIGUES *et al.*, 2020), que é um tributário de margem direita, cujo trecho urbano não apresenta dados que permitam a construção de ações efetivas na manutenção da qualidade da água, a partir de uma gestão urbana que seja alinhada com as diretrizes estabelecidas para esta gestão (BRASIL, 1997; 2005; 2011).

Na área urbana desse igarapé, o marco do processo de urbanização parte da Rodovia Constantino Pereira do Sacramento, perpassa pelo Conjunto Residencial Selecta, chega a confluência da rua Gregório Araújo Santos com a rodovia PA 125, dirige-se ao Lago Verde, até desaguar na margem direita do rio Uraim, já na rua Padre Carvalho. Este percurso é essencialmente urbano. Nele, o desmatamento teve início

com a chegada de pessoas atraídas pela oferta de terras (ASSIS; VALDAMBRINI; SOUZA, 2024) o que alterou o uso e ocupação do solo (VALE *et al.*, 2017).

Durante a evolução etária, desde a fundação até hoje (60 anos), a área urbana MACHADO; LOBO; TOURINHO, 2015), expandiu e avançou sobre o igarapé Paragominas, dantes chamado de Prainha (PINTO *et al.*, 2009). De acordo com relatos orais espontâneos ofertados pelos usuários da área contida na rodovia Constantino Pereira do Sacramento, havia um acúmulo de areia (aluvião), onde lavavam roupas e banhavam. O nome Prainha (CRUZ *et al.*, 2019) foi associado a esta formação arenosa. No espaço geográfico hoje ocupado pelo Residencial Selecta, havia inúmeras serrarias durante a economia extrativista madeireira que, atualmente, enfraqueceu (SOARES *et al.*, 2016).

Seguindo a linha evolutiva urbana no município de Paragominas, chegou-se à confluência da PA 125 com rua Gregório Santos Araújo, onde há uma formação lagunar, cujas residências do bairro Camboatã, já ocupam, com seus quintais, a parte da margem esquerda do igarapé Paragominas. Na sequência, tem-se o Lago Verde, área dantes utilizada como depósito de resíduos sólidos a céu aberto. Este local, para efeito de melhorias na paisagem cênica, é uma alteração do meandro natural do igarapé, tanto em largura quanto em profundidade (FARIAS; CALANDRINO, 2018).

Uma das modificações efetuadas foi a pavimentação asfáltica e cimentícia em ambas das margens esquerda e direita deste corpo d'água. Os processo de pavimentação urbana são fatores predominantes nas alterações da qualidade das águas superficiais associado ao escoamento superficial e a taxa de precipitação na área que adentram o corpo hídrico (SILVA, 2014). Outro fator é a deficiência da presença do saneamento básico, especialmente a captação de efluentes domésticos e o tratamento adequado dele (ANA, 2017; BRASIL, 2007).

Diante do exposto, justificou-se a realização desta pesquisa quanto a qualidade da água no trecho urbano do igarapé Paragominas. O objetivo foi a identificação da real situação das águas superficiais deste igarapé a partir da urbanização, e os fatores identificadores das alterações provocadas pelo desmatamento, pavimentação, saneamento básico, tanto nos parâmetros físico-químico e microbiológicos, sedimentação e alterações do habitat aquático que caracterizam a qualidade da água em função das legislações federais e municipais para tal qualidade.

Para melhor compreensão da coesividade entre os cinco artigos publicados componentes desta tese com os três cenários dela, elaborou-se esta síntese. No **Cenário 1**, o objetivo foi verificar a ocorrência do desmatamento no município de Paragominas (Artigo 1) e uso e ocupação do solo a partir de dados geoespaciais. Os dados indicaram que desmatamento acompanhou a expansão agrícola e a urbanização, mas provocou uma diminuição da área hídrica do município, no trecho urbano que foi dividido aleatoriamente em cinco áreas (A₁, A₂, A₃, A₄, A₅).

As consequências, tanto os impactos antrópicos quanto as condições ambientais, no trecho urbano do igarapé Paragominas, nas cinco áreas analisadas, foram identificadas e qualificadas no **Cenário 2**. Para tal, aplicou-se o Protocolo de Avaliação Rápida, onde foi calculado o índice de Integridade do Habitat – IIH, a partir de sete parâmetros identificados em cada delas, para qualificar o grau do estado ambiental em que se encontram especialmente em razão da presença de flora e fauna aquática. O dados obtidos permitiram classificar as áreas desde impactadas até altamente impactadas (Artigos 2 e 3).

Mas, o que tudo isto causou à qualidade da água do igarapé Paragominas no trecho urbano, foi analisado no **Cenário 3**. Os dados obtidos indicaram que à medida que a urbanização se eleva, e o saneamento básico não acompanha tal elevação,

verificou-se que a flora aquática se diversifica e é incrementada, mas a fauna tende a diminuir. O serviço ecossistêmico de provisão e o cultural como a balneabilidade em família, ainda ocorre em A₁, mas à medida que se analisaram as demais áreas, esta tendência diminuiu. Para a fauna, a concentração do oxigênio dissolvido, é diminuto, devido a presença de bueiros que desaguam no igarapé pesquisado. A presença da amônia não ionizada ou livre é outro fator de impacto que caracteriza o comprometimento da qualidade da água no trecho urbano (Artigos 4 e 5). Por isso, os órgãos gestores dos recursos hídricos de Paragominas, devem monitorar mais efetivamente não só os aspectos físico-químicos das águas que drenam a parte urbana de Paragominas.

REFERÊNCIAS

ALMEIDA, F. F. **O que as algas têm a dizer sobre o rio Negro? O uso de algas como bioindicadoras da qualidade ambiental do baixo rio Negro, Manaus-AM.** 2017 Tese (Doutorado em Ciências Biológicas) – Instituto Nacional de Pesquisas da Amazônia, Manaus, 2017.

ALMEIDA JÚNIOR, E. L.; LEME, P. C.; GONÇALVES, J. .L. S. Quantificação da amônia em tintura capilar. **Revista Científica da UERGS**, v. 8, n.º 03, p. 236-246, 2022.

ALVES, V. P. Determinantes do desmatamento no estado do Pará: uma análise com regressão quantílicas para os dados em painel. **Revista Brasileira de Gestão e Desenvolvimento Regional**, v. 17, n.º 3, p. 257-270, 2021.

ANA. Agência Nacional de Água e Saneamento Básico. **Atlas Esgotos:** despoluição de bacias hidrográficas. Brasília: ANA, 2017. Disponível em: [Atlas Esgotos](#). Acesso em: 12 mar. 2025.

ANA. Agência Nacional de Água e Saneamento Básico. **Atlas Água:** segurança hídrica do abastecimento urbano. Brasília: ANA, 2021 Disponível em: [Atlas Águas \(2021\): segurança hídrica do abastecimento urbano](#). Acesso em: 30 mars. 2025.

ANH, N. *et al.* Influences of key factors on river water quality urban and rural areas: a review. **Cases Studies in Chemical and Environmental Engineering**, v. 8, 100424, 2023.

ASSIS, N. R.; VALDAMBRINI, B.; SOUZA, A. M. Paragominas – PA e a crise ambiental na Amazônia: uma experiência bem-sucedida do planejamento municipal. **Caderno Prudentino de Geografia**, v. 2, n.º 46, p. 204-223, 2024.

BERLANDA, A. *et al.* Avaliação temporal e espacial da qualidade das águas superficiais da bacia hidrográfica doo rio Desquite, Santa Catarina. **Engenharia Sanitária e Ambiental**, v. 26, n.º 1, p. 45-51, 2021.

BORGES, G. P. R. **Desmatamento na Amazônia: um estudo bibliográfico.** Monografia (Bacharelado em Ciência e Tecnologia) – Universidade Federal do Pampa, Porto Alegre, 2023.

BRASIL. **Lei n.º 9.433**, de 8 de janeiro de 1997. Institui a Política Nacional de Recursos Hídricos, cria o Sistema Nacional de Gerenciamento de Recursos Hídricos, regulamenta o inciso XIX do art. 21 da Constituição Federal, e altera o art. 1º da Lei nº 8.001, de 13 de março de 1990, que modificou a Lei nº 7.990, de 28 de dezembro de 1989. Disponível em: [L9433](#). Acesso em: 10 abr. 2025.

BRASIL. **Resolução n.º 357**, de 17 de março de 2005. Dispõe sobre a classificação dos corpos de água e diretrizes ambientais para o seu enquadramento, bem como estabelece as condições e padrões de lançamento de efluentes, e dá outras providências. Disponível em:

conama.mma.gov.br/?option=com_sisconama&task=arquivo.download&id=450.

Acesso em: 30 mar. 2025.

BRASIL. **Lei n.º 11.445**, de 05 de janeiro de 2007. Estabelece as diretrizes nacionais para o saneamento básico; cria o Comitê Interministerial de Saneamento Básico; altera as Leis n.ºs 6.766, de 19 de dezembro de 1979, 8.666, de 21 de junho de 1993, e 8.987, de 13 de fevereiro de 1995; e revoga a [Lei nº 6.528, de 11 de maio de 1978](#).

Acesso em: 30 mar. 2025.

BRASIL. **Resolução n.º 430**, de 13 de maio de 2011. Dispõe sobre as condições e padrões de lançamento de efluentes, complementa e altera a Resolução no 357, de 17 de março de 2005, do Conselho Nacional do Meio Ambiente-CONAMA. Disponível em: conama.mma.gov.br/?option=com_sisconama&task=arquivo.download&id=627.

Acesso em: 30 mar. 2025.

BRASIL. **Lei n.º 12.651**, de 25 de maio de 2012. Dispõe sobre a proteção da vegetação nativa; altera as Leis n.ºs 6.938, de 31 de agosto de 1981, 9.393, de 19 de dezembro de 1996, e 11.428, de 22 de dezembro de 2006; revoga as Leis n.ºs 4.771, de 15 de setembro de 1965, e 7.754, de 14 de abril de 1989, e a Medida Provisória n.º 2.166-67, de 24 de agosto de 2001; e dá outras providências. Disponível em: [L12651](#).

Acesso em: 30 mar. 2025.

CAI, H., M. *et al.* An analysis of the relationship between water pollution and economic growth in China, considering the contemporary correlation of water pollutants. **Journal of Cleaner Production**, 276, 2020.

CASATTI, L. Alterações no código florestal brasileiro: impactos sobre a ictiofauna. **Biota Neotropica**, V. 10, N.º 4, P.31-34, 2010.

CHAMORRO, P. Poluição invisível nas águas amazônicas ameaça populações e biodiversidade. Revista National Geographic eletrônica. 2021. Disponível em: [Poluição invisível nas águas amazônicas ameaça populações e biodiversidade | National Geographic](#). Acesso em: 10 abr. 2025.

CRUZ, M. S. *et al.* Impactos ambientais oriundos da urbanização às margens do rio Prainha, Paragominas – PA. In PEREIRA JÚNIOR, A.; JESUS, E, S.; RIBEIRO, J. M. F. R. (Org.). **As múltiplas visões sobre o meio ambiente e aos impactos ambientais**, v. 2. 2019, cap. 16, p. 264-279.

DAR, M. A. *et al.* Microplastic pollution: a global perspective in surface waters, microbial degradation, and corresponding mechanism. **Marine Pollution Bulletin**, v. 210, 2025.

EMPINOTTI, V. L. *et al.*, Desafios de governança da água: conceito de territórios hidrossociais e arranjos institucionais. **Estudos Avançados**, v. 35, n.º 102, p. 107-192, 2021.

FARIAS, C. S.; CALANDRINO, F. P. **O município verdes e suas áreas urbanas não tão verdes: avaliação qualitativa e quantitativa das principais áreas verdes**

urbanas de Paragominas – PA. 2018. Monografia (Bacharelado em Engenharia Florestal) – Universidade Federal Rural da Amazônia. Paragominas, 2018.

FREITAS, M. F.; PIRES, M. M.; BENINCÁ, D. Fragilidades e potencialidades na gestão dos resíduos sólidos urbanos no Brasil. **Revista Brasileira de Gestão Urbana**, v. 16, e20230971, 2024.

FRITZSONS, E. *et al.* A influência da floresta ciliar sobre a temperatura das águas do rio Capivari, região cárstica curitibana. **Floresta**, v. 35, n.º 3, p. 395-407, 2005.

GALVÃO, P. Influência do uso do solo na taxa de infiltração da água da bacia hidrográfica dos igarapés 54 e 7, Paragominas, PA. **Holos**, v. 20, n.º2, p. 303-319, 2020.

GAMA, A. S. *et al.* Análise da dinâmica do uso da terra e seus reflexos na cobertura vegetal na microbacia hidrográfica do igarapé do Sete, no município de Paragominas, estado do Pará. *In: Seminário de Iniciação Científica da Universidade Federal Rural da Amazônia - UFRA.* 2006. Disponível em: [Microsoft Word - Adriano da Silva Gama.doc](#). Acesso em 11 br. 2025.

GODOY, H. C.; LIMA JÚNIOR, S. E. Distribuição espacial da ictiofauna e sua relação com as características ambientais na microbacia do córrego Tarumã (Alto Rio Paraná, Brasil). **Oecologia Australis**, v.26, n.º 1, p. 7-18, 2022.

IBGE. Instituto Brasileiro de Geografia e Estatística. IBGE atualiza dados geográficos de estados e municípios brasileiros. 2020. Disponível em: [IBGE atualiza dados geográficos de estados e municípios brasileiros | Agência de Notícias](#). Acesso em 10 mar. 2025.

KOHLER, M. R. *et al.* O desmatamento da Amazônia brasileira sob o prisma da pecuária: a degradação dos recursos hídricos no contexto da região norte de Mato Grosso. **Research, Society and Development**, v. 10, n.º 11, e66101119252, 2021a.

KOHLER, M. R. *et al.* Desmatamento e degradação das microbacias hidrográficas de captação ao abastecimento urbano: a produção do déficit hídrico na cidade de Alta Floresta, MT. **Ciência Geográfica**, v. 25, n.º 3, p. 998-1021, 2021b.

JONES, F. Brasil lança 3,44 milhões de toneladas de lixo plástico no mar por ano. **Revista eletrônica Pesquisa FAPESP**, ed. 321, 2022. Disponível em: [Brasil lança 3,44 milhões de toneladas de lixo plástico no mar por ano : Revista Pesquisa Fapesp](#). Acesso em 10abr. 2025.

LACERDA, N. P. Rodovia BR 163 e o desmatamento na Amazônia. **Revista Brasileira de ESTUDO E Gestão e Desenvolvimento Regional**, v. 01, n.º 01, 147-155, 2024.

LI, J. *et al.* Copula-based analysis of socio-economic impact on water quantity and quality: a case study of Yitong river, China. **Science of the Total Environment**, n.º 859, 160176, 2023.

LI, X. *et al.* Surface water environmental carrying capacity and surface water quality based on economy-society-environment nexus – Evidence from China. **Water – Energy Nexus**, n.º 6, p. 231-243, 2023.

LIMA, M. V. Atividade agropecuária e a transformação da mata ciliar do açude Orós/CE: um trabalho com alunos e pequenos pecuaristas. **Brazilian Journal of Development**, v. 7, n.º 9, p. 91148-91162, 2021.

LOURENÇO, R. W. *et al.* Reflexos ambientais do desenvolvimento e expansão das atividades humanas sobre a qualidade da água. **Revista Brasileira de Geografia Física**, v. 15, n.º 01, p. 175-198, 2022.

MACHADO, L. M. V.; LOBO, M. A. A.; TOURINHO, H. L. Z. Dispersão e fragmentação urbana em cidades intermediárias: o caso de Paragominas (PA). **Acta Geográfica**, v. 9, n.º 20, p. 1-15, 2015.

MEDEIROS, C. K.; RUFINO, I. A. A.; ARAGÃO, R. Consumo de água e crescimento urbano: análises espaciais e relações possíveis. **Revista Brasileira de Gestão Urbana**, n.º 16, e20230039, 2024.

MONTAGNER, C. C. *et al.* Microplásticos : ocorrência ambiental e desafios analíticos. **Química Nova**, n.º 10, p. 1328-1352, 2021.

MOREIRA FILHO, M. W. P.; BRELAZ, A. S. Deficiência no atendimento de coleta de resíduos sólidos na totalidade de ocupação Vista Alegre do Juá, Santarém – PA. *In*: Simpósio de Gestão Ambiental e Biodiversidade. 11. Rio de Janeiro. 2022. **Anais eletrônicos**. Disponível em: [Anais Simpósio de Gestão Ambiental e Biodiversidade | Even3 Publicações](#). Acesso em 10 abr 2025.

MO, W. *et al.* Impacts of land use patterns on river water quality: the case of the Dongjiang Lake Basin, China. **Ecological Informatics**, 75, 2023.

NASCIMENTO, C. E. S. **A importância das matas ciliares do rio São Francisco**. Petrolina: Embrapa Semiárido, 2001. Documentos, 179.

OMER, N. H. Water quality Parameters. *In*: SUMMERS, J. K. **Water Quality**. Science, assessment, and policy. London: InthechOpen, 2020, chapter 1. s/p.

PARAGOMINAS. **Diagnóstico da realidade municipal**. Revisão do Plano Diretor. Prefeitura Municipal de Paragominas, 2020.

PICANÇO, T. E. F. *et al.* Diagnóstico da percepção dos moradores da ocupação vista alegre do Juá/Santarém/PA à questão do descarte de resíduos orgânicos e o uso de compostagem doméstica. *In*: Simpósio de Gestão Ambiental e Biodiversidade. 11. 2022. *Online*. **Anais eletrônicos**. Disponível em: [11º Simpósio de Gestão Ambiental e Biodiversidade](#). Acesso em: 10. Abr. 2025.

PINTO A. *et al.* **Diagnóstico Socioeconômico e Florestal do município de Paragominas**. Relatório Técnico. Belém: Instituto do Homem e Meio Ambiente da Amazônia – Imazon, 2009.

PRESTES, A. G. *et al.* Impactos da urbanização na qualidade dos igarapés de Humaitá: um estudo baseado no Protocolo de Avaliação Rápida. *In: Encontro Brasileiro de Ictiologia*. 25. Tocantins. 2025. **Anais eletrônicos**. Disponível em: [IMPACTOS DA URBANIZAÇÃO NA QUALIDADE DOS IGARAPÉS DE HUMAITÁ: UM ESTUDO BASEADO NO PROTOCOLO DE AVALIAÇÃO RÁPIDA | Realize Editora](#). Acesso em: 30 mar. 2025.

QUEIROZ, L. G. Microplásticos: uma abordagem introdutória. *In: POMPÊO, M. RANIBORGES, PAIVA, T.C. B. Microplásticos nos ecossistemas: impactos e soluções*. São Paulo: Universidade de São Paulo, Instituto de Biociências, 2022, capítulo 1, p. 1-7.

RAHMANI, V. *et al.* Examining storage capacity loss and sedimentation rate of large reservoirs in the Central U. S. Great Palins. **Water**, v. 10, p. 190, 2018.

RAMLEE, M. A. Brief photographic documentation of floral and faunal diversity in the polluted Gombak river ecosystem, Kuala Lumpur, Malaysia. **International Journal of Hydrology**, v. 9, n.º 1, p. 22-25. 2025.

REIS, J. A. T.; MENDONÇA, A. S. F. Análise técnica dos novos padrões brasileiros para amônia em efluentes e corpos d'água. **Engenharia Sanitária e Ambiental**, v. 14, n.º 3, p. 353-362, 2009.

RIBEIRO, B, R, *et al.* Cobertura da vegetação nativa e taxas de desmatamento em bacias hidrográficas no Brasil. Rio de Janeiro: **Projeto Planafior**. Nº 5, 2022. Disponível em: [Planafior-estudo-05-cobertura-taxa-desmatamento-BR.pdf](#). Acesso em: 15 abr. 2025.

RODRIGUES, R. S. S. *et al.* Análise dos efeitos e um evento extremo de chuva cobre ao escoamento superficial em uma pequena bacia hidrográfica rural Amazônica. **Revista Brasileira de Climatologia**, v. 26, 368-392, 2020.

SANTOS, C. H. A. **Influência da Integridade do Habitat e das variáveis ambientais sobre a comunidade de Odonata em igarapés florestados em Roraima**. 2019. Dissertação (Mestrado em Recursos Naturais) – Universidade Federal de Roraima, Boa Vista, 2019.

SANTOS, D. T.C.; SANTOS, V. C. Impactos ambientais macroscópicos e qualidade da água em nascentes localizadas na Vila Bananeira, Arapiraca – AL. **Diversitas Journal**, v. 6, n.º1, p. 481-498, 2021.

SANTOS, G. P.; OLIVEIRA, L. L.; MORTATI, A. F. Aplicação do índice de Integridade do Habitat e sua relação com a qualidade da água e hidrodinâmica de igarapés urbanos amazônicos. *In: Simpósio Brasileiro de Recursos Hídricos*. 22.2017. Santa Catarina. **Anais Eletrônicos**. Disponível em: [Ethan Frome](#). Acesso em: 30 abr. 2025

SANTOS, G. P *et al.* Efeitos da Integridade ambiental da zona ciliar e sua influência na qualidade da água de igarapés urbanos em Santarém-PA, Amazônia, Brasil. **Revista Brasileira de Geografia Física**, v. 14, n.º 7, p. 4035-4055, 2021.

SANTOS, G. S. N.; AQUINO, R. N.; SANT'ANA, A. L. Projetos de recuperação de matas ciliares no Brasil: uma análise comparativa de dois projetos na Amazônia com projetos bem-sucedidos em outras regiões brasileiras. **Revista Contribuciones a las Ciencias Sociales**, v. 17, n.º 10, p. 01-23, 2024.

SELIM, A. *et al.* Predictive models for dissolved oxygen in an urban lake by regression analysis and artificial neural network. **Total Environment Research Theme**, v. 7, 2023.

SILVA, J. G. S. *et al.*, Aplicação de protocolo de avaliação da integridade ambiental na bacia hidrográfica do rio Araranguá, SC. **Boletim Paulista de Geografia**, n.º 109, p. 147-171, 2023.

SILVA, L. C. T. **Avaliação do projeto público “Paragominas: Município Verde” sob a ótica das mudanças climáticas**. 2014. Dissertação (Mestrado em Desenvolvimento Sustentável do Trópico úmido) – Universidade Federal do Pará, Belém, 2014.

SOARES, D. A. S. *et al.* Uso do território em Paragominas (PA): espaço geográfico e classe sociais. **Revista Tocantinense de Geografia**, n.º 008, p. 1-28, 2016.

TELES, R. R.; SANTOS, J. C.; PINHEIRO, E. C. N. P. A importância da preservação de matas ciliares. **Brazilian Journal of Development**, v.8, n.º 11, p. 75348-75360, 2022.

TORDIN, C. **Coleta deficiente e baixa reciclagem ainda são desafios para a gestão do lixo no Brasil**. São Paulo: Embrapa Meio Ambiente. 2025. Disponível em: [Coleta deficiente e baixa reciclagem ainda são desafios para gestão do lixo no Brasil - Portal Embrapa](#). Acesso em 10 abr. 2025

TUNDISI, J. G.; WENDLAND, E. C.; MOENDIONDO, E. M. Urban Waters. **Brazilian Journal of Biology**, v. 83, e250000, 2023.

VALE, J. R. B. *et al.* Mapeamento do uso da terra e cobertura vegetal do município de Paragominas, sudoeste paraense. *In*: Congresso Brasileiro de Cartografia. 27. 2017. Rio de Janeiro. **Anais eletrônicos**. Disponível em: [INSTRUÇÕES AOS AUTORES PARA VERSÃO FINAL DE TRABALHOS PARA O XXI CBC](#). Acesso em 10 abr. 2025.

VENTURIERI, A. *et al.* Utilização de imagens Landsat e CBERS na avaliação da mudança do uso e cobertura da terra e seus reflexos na qualidade da água em microbacia hidrográfica do município de Paragominas, Pará. *In*: Simpósio Brasileiro de Sensoriamento Remoto. 12. 2005. Goiás, **Anais eletrônicos**. Disponível em: [Microsoft Word - Paragominas SBSR](#). Acesso em 10 mar. 2025.

VERAS, S, T, S, *et al.* Nota técnica - caracterização qualitativa do esgoto bruto. **Engenharia Sanitária e Ambiental**, v.3, n.º 4, p. 3-14. 2023.

VIEIRA, A. B. C. D. The toxicity of ammonia: a Theoretical approach. *In: Revolutionizing learning: innovative approaches in educational sciences*. 2024, Chapter 5, p. 61-74.

Wang, W., Yang, P., Xia, J., *et al.* Impact of land use on water quality in buffer zones at different scales in the Poyang Lake, middle reaches of the Yangtze River basin. **Science of The Total Environment**, 896, 2023.

WASIS, B.; HARLAN, D.; PUTRA, M. H. W. Impact of forest land cover on runoff, erosion and sedimentation in the Karai Watershed, Simalungun Regency, North Sumatra Province, Indonesia. **Archives of Agriculture and Environmental Science**, v. 5, n.º 1, p. 40-49, 2020.

WERNER, D. Challenger, and opportunities for urban water that is fit you play in. **Hydrology**, n.12, p.75. 2025.

ZHANG, W. *et al.* Variations in dissolved oxygen and aquatic biological responses on China's coastal seas. **Environmental Research**, n.º 223, 2023.

ZHAO, G. *et al.* Study on the coupling model of urbanization and water environment with basin as a unit: a study on the Hanjiang basin in China. **Ecological Indicators**, n.º 131, 108130, 2021.

Cenário 1. Desmatamento no município de Paragominas, uso da terra e impactos dos recursos hídricos em Paragominas, Pará.

Geospatial analysis of deforestation, land use and impacts of water resources in Paragominas, Pará

Resumo

Os dados geoespaciais têm se mostrado eficazes na identificação e no monitoramento do desmatamento, do uso da terra e dos recursos hídricos em regiões com foco predominante na agricultura e na pecuária. O objetivo deste estudo foi avaliar o uso do georreferenciamento na identificação de casos de desmatamento e uso da terra e seus respectivos impactos nos recursos hídricos em Paragominas, Pará, durante os anos de 2000, 2005, 2010 e 2021. A metodologia utilizou uma abordagem indutiva, integrando métodos quantitativos e qualitativos e observações de campo. Os dados de georreferenciamento mostraram que o desmatamento ocorreu desde a criação do município, resultando em uma redução de 83,64% na cobertura florestal. Em 2000, a área urbana ocupava 1.333 hectares e, em 2021, aumentou para 2.026 hectares. A área de águas superficiais diminuiu em 207,91 hectares entre 2000 e 2021. De 2010 a 2021, as pastagens diminuíram de 187.561 hectares para 125.229 hectares. A agricultura também evoluiu, passando de 1.342 hectares em 2000 para 103.162 hectares em 2021. Dos 11 projetos de assentamento, cinco estão completamente localizados na bacia do rio Uraim, e outros dois estão parcialmente localizados. A literatura analisada revela que a água se origina do rio Uraim, que passa por propriedades rurais e comunidades agrícolas como a Colônia do Uraim, resultando em deposição de sedimentos, compactação do solo, redução da capacidade de infiltração e recarga da bacia. Além disso, o afluente da margem direita, o igarapé Paragominas, tem 1,5 km de margens desenvolvidas. A análise espacial utilizando dados geoespaciais é vital para identificar áreas desmatadas e realizar estudos complementares sobre o uso da terra, ocupação e qualidade da água. Esses estudos são fundamentais para a elaboração de planos de gerenciamento de recursos naturais para Paragominas.

Palavras-chave: agricultura familiar, georreferenciamento, APP's, qualidade da água, desmatamento.

ABSTRACT

Geospatial data has proven effective in identifying and monitoring deforestation, land use, and water resources in regions with a predominant focus on agriculture and livestock. The purpose of this study was to assess the use of georeferencing in identifying instances of deforestation and land use, and their respective impacts on water resources in Paragominas, Pará, during the years 2000, 2005, 2010, and 2021. The methodology utilized an inductive approach, integrating quantitative and qualitative methods along with field observations. Georeferencing data showed that deforestation has taken place since the establishment of the municipality, resulting in an 83.64% decrease in forest cover. In 2000, the urban area occupied 1,333 hectares and in 2021 it increased to 2,026 hectares. The surface water area decreased by 207.91 hectares between 2000 and 2021. From 2010 to 2021, pastures decreased from 187,561 hectares to 125,229 hectares. Agriculture also evolved from occupying 1,342 hectares in 2000 to 103,162 hectares in 2021. Of the 11 settlement projects, five are completely located within the Uraim river basin, and two others are partially located

there. The literature analyzed reveals that water originates from the Uraim River, which runs through rural properties and farming communities such as Colonia do Uraim, resulting in sediment deposition, soil compaction, reduced infiltration capacity, and basin recharge. Furthermore, the right bank tributary, the Paragominas stream, has 1.5 km of developed banks. Spatial analysis utilizing geospatial data is vital for identifying deforested areas and conducting complementary studies on land use, occupation, and water quality. These studies are instrumental in devising natural resource management plans for Paragominas.

Keywords: family farming, georeferencing, APP's, water quality, deforestation.

1 INTRODUCTION

Changes in land use, especially the conversion of forest areas to other uses, have become visible and have been a factor of global concern (Ellis *et al.*, 2017; Peter *et al.*, 2012; Schubert *et al.*, 2019) and national (Rezende *et al.*, 2018). To assist in the process of identification, characterization, and quantification of these processes on the use and occupation of land/land, spatial technologies are used, tools that have proven to be very efficient for studies of these natures (Jamal *et al.*, 2018; Mercier *et al.*, 2019).

For an effective ordering of this loss, the use of remote sensing is of fundamental importance, as it allows differentiating the types of vegetation that still exist through spectral indices such as the *Normalized Difference Vegetation Index* (NDVI), the normalized difference vegetation index, as well as the microphysical properties of agricultural areas, which contributes to more effective studies in the control and growth of these production systems (Watrin *et al.*, 2007).

In Brazil, satellite images reveal deforestation in its five biomes, including the Amazon (Souza Júnior, 2020; Messias & Amorim, 2021; Araujo *et al.*, 2022). Within the northern Amazon region, the state of Pará comprises 144 municipalities and faces significant challenges in monitoring its forests. Consequently, Pará has become a pioneer in the adoption of innovative technologies for environmental management, as evidenced by studies (Hassan, 2019; Santos *et al.*, 2017; Tritsch *et al.*, 2016).

Deforestation in Pará is linked to predominant production systems, such as cattle ranching water bodies, resulting in the loss of vegetation cover in areas now designated as Permanent Protection Areas (PPAs), including riparian forests. Consequently, these water bodies have become vulnerable to morphometric changes and degradation of water quality (Alves *et al.*, 2014).

In Paragominas, a city where significant loss of vegetation occurred, settlers began arriving in the 1930s. In 1960, this influx led to the emergence of two developmentalist fronts: 1) pioneering and 2) expansion, which stimulated economic activities in the area. In this period, logging was the main economic activity. However, the degradation of pastures and the inappropriate use of chemical agents caused cattle to become malnourished and the market to suffer losses (Soares *et al.*, 2016).

Two years later, in 1962, the first colony was established with the presence of farmers from São Miguel do Guamá in search of land for agricultural cultivation (Rocha & Maia, 2018). This situation of family farming was driven by the opening of the BR-010 or Belém-Brasília highway, which gave rise to an economic dichotomy in Paragominas: logging and increased agriculture. This statement is related to the fact that, in 1995, the number of agricultural colonies was already more than 20, and each of them occupied an area equal to 20 km² (Santos *et al.*, 2015). In addition to these two economic activities, a third one emerges: cattle raising, which has become the priority activity in the areas of family farming (Guia *et al.*, 1999).

Another process of family farming is called the "settlement of agrarian reform." In reality, it is a set of agricultural units installed by the National Institute of Colonization and Agrarian Reform (INCRA). These units, called "lots", are intended for families without economic conditions to acquire a rural area. After the session, these families must live and economically explore the boundaries of these areas. There are also areas available for the construction of churches, schools, agro-industries, among others (INCRA, 2020).

Since the creation of this autarchy, from the enactment of Decree-Law No. 1,110 (Brasil, 1970), from the merger of two others: the Brazilian Institute of Agrarian Reform (IBRA) and the National Institute of Agrarian Development (INDA), it has assumed three functions: 1. Promote agrarian reform; 2. Rural development, especially in the North; and 3rd. Reduce conflicts over land ownership. 20 years later, INCRA began the phase of rural settlement projects in all regions of the national territory, including the state of Pará (Coelho & Costa, 2022).

As for the size of the settlement areas, they are currently measured in fiscal modules, according to Law 6.746 (BRASIL, 1979), whose unit is the hectare (ha). To determine the extent of the area, INCRA is based on economic use (vegetables; permanent or temporary agricultural crops, livestock, or forestry activities). The size of the area varies according to the Brazilian municipality. In the state of Pará, values between 70 and 80 hectares were established, and in Paragominas, one of the 144 municipalities in this state, the value is equivalent to 55 hectares (PARÁ, 2021).

In addition to the logging already active at the time, there was an increase in the number of cattle ranchers who, in 1997, already occupied 96% of the city's area (14,233 km²), and mining activities. Another economic sector at the time, logging, developed due to the degradation of pastures and the inappropriate use of chemical agents, which led to the thinning of cattle and the loss of the market (Soares *et al.*, 2016). Despite this economic triad, the municipality of Paragominas has solid economic bases in beef cattle, timber extraction, and soybean cultivation (Chaves *et al.*, 2018; Young & Bakker, 2015).

In Paragominas, there are two main rivers: Paragominas and Uraim. The latter drains the city center towards the northwest and serves as the main source of water for the Paragominas Sanitation Company (SANEPAR), which treats, distributes, and supplies water to the urban population. Deforestation within the Permanent Protection Area around these water bodies, driven by agricultural expansion, livestock, and cattle irrigation, raises concerns about declining water quality (Pereira *et al.*, 2016). Similar problems also affect tributaries of the Uraim River, such as the Igarapé 54 and the Parariquara (Chaves *et al.*, 2019; Neves *et al.*, 2022).

Monitoring these environmental impacts requires a comprehensive approach, considering both the vast territorial extent and the assessment of Permanent Protection Areas (PPAs) as conserved or degraded. In Paragominas, previous academic research has used georeferencing for this purpose (Cardoso *et al.*, 2017; Moura & Rocha, 2016; Pimentel, 2016; Ribeiro *et al.*, 2017; Santos *et al.*, 2015; Soares *et al.*, 2016).

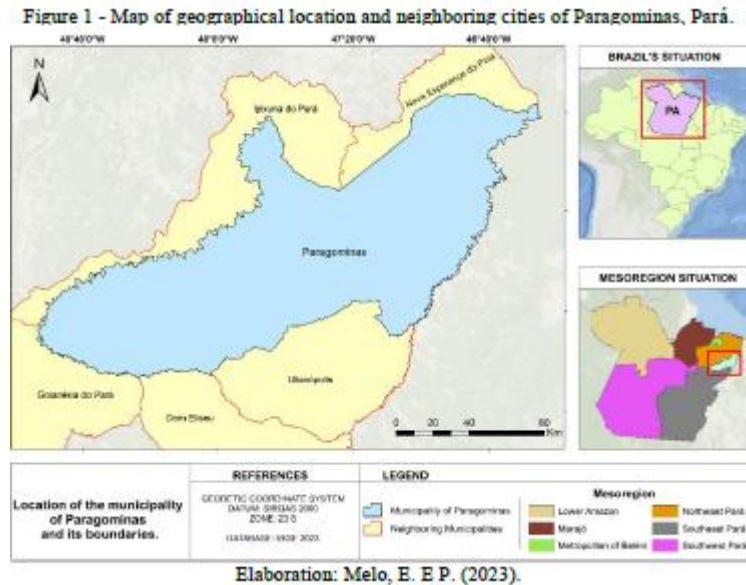
There are numerous and widespread environmental issues, but technologies such as remote sensing allow for more accurate assessments of concerns such as deforestation, land use and livestock, which can affect water resources. This context and the potential for acquiring new data underscore the importance and relevance of this research, leading to the central question: can the relationship between deforestation, land use and occupation in the Uraim River watershed, together with

potential variations in water quality parameters, be effectively demonstrated through spatial data obtained by remote sensing?"

2 MATERIAL AND METHODS

2.1 CONTEXT PARAGOMINAS

The municipality of Paragominas (parallels 2°38' and 3° 40" S; 46°27" and 48°27" W), is located 316 km from the Metropolitan Region of Belém (RMB), southeast of the State of Pará, whose geographical limits involve Nova Esperança do Piriá, Ipixuna do Pará, Ulianópolis, Goianésia do Pará and Dom Eliseu (Figure 1).



The climate of Paragominas, according to Köppen, is classified as tropical rainy, with a prolonged period of drought. In Thornthwaite's classification, it is a humid tropical climate with an extensive water deficit. The average annual temperature is equal to 26.3°C, with relative humidity around 81% (Rodrigues *et al.*, 2020). The soil has its genesis in the Itacaiúnas Formation, with a predominance of a Dystrophic Yellow Latosol (81.38% of the total area of the municipality), suitable for the use of intensive agriculture. The vegetation is characterized as belonging to the dense Subperenifoliated Equatorial Forest: submontane and lowland tropical forest and Dense Fluvial Tropical Forest (Rodrigues *et al.*, 2003).

2.2 METHOD

In the elaboration of this research, the deductive method was adopted, since in the synthesis written by Pereira *et al.* (2018), these authors affirm that such a method allows the association with: 1) quantitative, which allows the numerical expression of the data found and the object of study/research; 2) qualitative, whose data analysis tends to be an inductive process, in addition to the observational nature. According to these authors, this allows greater systematization of information and expansion of ideas on the subject under analysis.

2.3 IMAGING AND MAPPING

Image processing techniques, with MapBiomass, were used to evaluate changes in land use and land cover in the Uraim River watershed in Paragominas (Chart 1).

Chart 1 - Sensors, platforms, and images used in this research.

Images			
Satellite's	Year	Collection	Observations
TM/Landsat 5, 7, e 8	1984, 1999 and 2013.	1.0 to 7.1	With geometric, radiometric, and atmospheric corrections.
Spatial Resolution of pixel			30 m.
Standardized difference vegetation index			
Sensors	Year	Collection	Observations
Thematic Mapper (TM)	1984, 1999 and 2013.	--	Agriculture, forestry, water monitoring and urban area.
Land cover and use			
Spatial Analysis Platforms			
Platform	--	--	Observations
Google Earth Engine (GEE)	2010	--	Analysis and visualization of spatial data; statistical treatments: Excel and Libre Office.
Water resources – micro basin Uraim river.			
Spatial Analyst Tools e Classification (Quantile)	--	--	Tool contained in the ArcGIS 10.6 software.
3D Analyst	--	--	Tool available in ArcGIS 10.6 software.

Source: Authors (2023).

The nomenclatures of the Classes followed what was established in the structuring of MapBiomass: 1. Forests (subdivisions are not considered); 3. Agriculture (subdivisions 3.1, Pasture and 3.2 Agriculture are considered); 4. Non-vegetated area (4.1, Urban area); 5. Water body, without subdivisions. For the composition of the slope of the Uraim River micro basin, level curves were used. Among them, a distance equal to 12 m was maintained. The interpolation of the data referring to the slope of the micro basin under study was performed with the application of the 3DAnalyst tool, available in the ArqGis 10.6 software. The slicing classification was based on that described by Crepani *et al.* (2001), for vulnerability factors and trend classes (Table 1).

Table 1. Values established for the slope of the Uraim River watershed, related to vulnerability coefficients.

Slope (%)	Morphometric class	Vulnerability coefficient
< 2	Very low	1,0
2 a 6	Low	1,5
6 a 20	Average	2,0
20 a 50	High	2,5
> 50	Very high	3,0

Elaborated from data contained in Crepani et al. (2001)

For this research, we considered "pasture" the places that have already served livestock and agricultural planting, and that are without servitude for both cases (Dias-Filho, 2012); "agriculture" all those practices used for the preparation of the land / soil as ploughing, where food of plant origin is produced, and has utility also in the creation of animals that can be useful to man (Agriculture | Michaelis On-line (uol.com.br); as "urban area", the following definition was chosen: the urban area of each municipality must be established by municipal law, and that in it/from it, taxes are levied, as well as the so-called "Master Plan". In this area, there is the proximity between the architectural units; defined streets, among other aspects (IBGE, 2023).

2.4 GETTING AND SELECTING SECONDARY DATA

Secondary data were obtained from access to *public access websites* such as: Brazilian Institute of Geography and Statistics (IBGE), Secretariat of Environment and Sustainability of the State of Pará (SEMAS-PA), City Hall of Paragominas, Pará, Portal

de Periódicos da Coordenação e Aperfeiçoamento de Pessoal de Nível Superior (CAPES). *Web of Science*, Google Scholar, among others. For the selection of the literature in these search sites, it was necessary to construct descriptors, applying the strategy that involves the Problem (P), the Intervention (I), the Control (C) and the Objective (O). In the case of this research, this last strategic marker is replaced by Results (R), which proved to be more effective in its focus (Chart 2).

Chart 2 - PICO Strategy for the analysis of deforestation in the Uraim River watershed, Paragominas, Pará.

PICO	Characteristics
Problem	Deforestation over the Uraim River basin; land use and occupation and impacts on water resources, from the overlapping of Maps.
Intervention	Identification of deforested areas, and classes of land use and occupation with the elaboration of a map from data contained in MapBiomass ⁴ , report 7 (2022), with a resolution of 30 m.
Control	Non-application to prevent pollution
Results	Is there still the presence of PPA in the urban area of the Uraim River watershed?

⁴adapted from the contained Munene & Hall (2019).

3). After the partial selection, the final selection was performed in five stages (Chart

Chart 3. The five steps that enabled the method used in this research to be carried out.

STEPS	CHARACTERISTICS
Identification	Access to databases: Digital Library of Theses and Dissertations (BDTD), access portal of the Coordination for the Improvement of Higher Education Personnel (CAPES), Scientific Electronic Library Online (SciELO), Brazilian Society of Genetic Resources, Mendeley, Science Direct, both contained in the Scopus database, to obtain literature on water management; management, and conservation in the Amazon.
Screening	Application of cut-off according to year of publication: 2000 to 2022 ¹ . Checking for the presence of selective descriptors: Environmental Protection Area (APA); deforestation, water quality, associated with the Boolean tree structure, in the sections: Title; abstract; keywords / palabras clave. 1. water quality index and urban water or water and APP. 2. Urban rivers plus water pollution and/or contamination and deforestation. 3. The Uraim river basin and APP deforestation.
Eligibility	The sums of the literature containing at least one of the isolated descriptors of association in at least one of the sections analyzed were eligible for the composition of this research.
Exclusion	Literature that had not been published within the established timeframe and/or that did not present the selective descriptors, alone or in association, was excluded. A similar procedure was carried out with authors found in the four databases accessed and whose research content was similar to another that had already been screened.
Inclusion	Literature similar to the subject of this research in terms of the use of remote sensing, deforestation in APPs, land use and occupation and water quality after deforestation were included in this review.

¹ This period is justified due to the storage of data in the links of the ministerial and environmental control bodies at federal, state, and municipal level. Source: Authors (2023).

Statistical Analysis

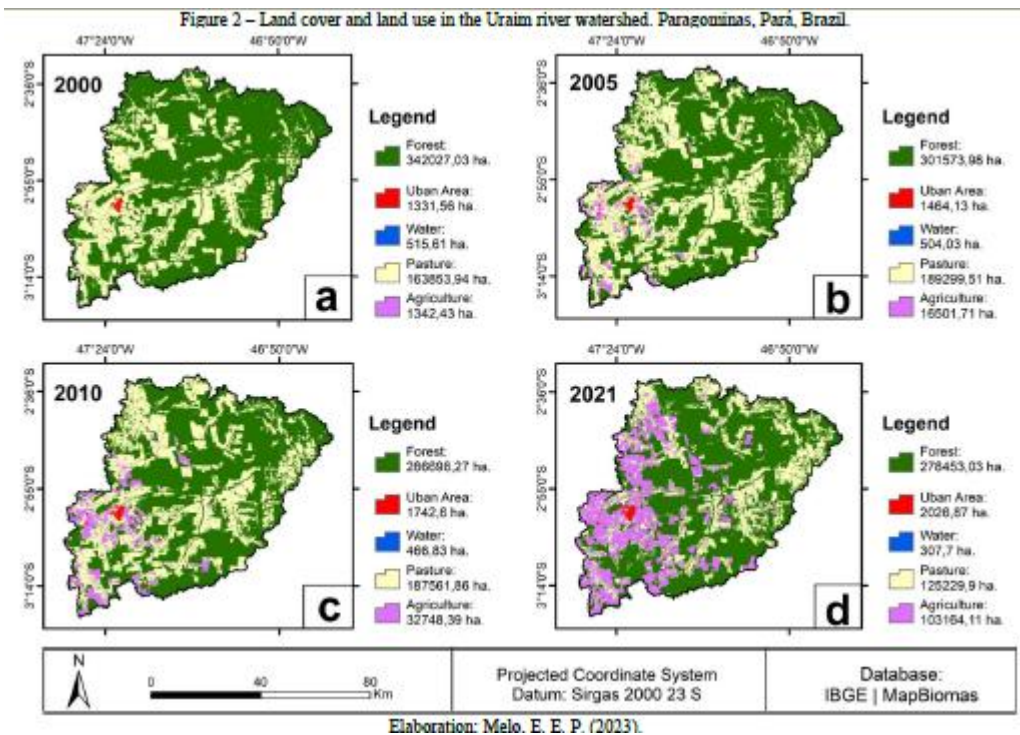
Pearson's Correlation and Simple Linear Regression were used to verify the effect of the georeferenced classes: forest, urban area, pasture, and agriculture, on the surface water area.

3 RESULTS

3.1 DEFORESTATION

The data obtained and analyzed for the forest that occurred in the municipality of Paragominas-PA indicated that in 2000 the forest area was 342,027.03 ha (Figure 2a); in 2005, 301,573.98 ha (Figure 2b); in 2010, it was reduced to 286,698.27 ha (Figure 2c) and, in 2021, to 278,423.03 ha (Figure 2d), which corresponds to a loss of forest area of 83.64%. It is observed that the loss of forest area was more accentuated

between 2000 and 2005 (- 40,453.05 ha). From 2005 to 2010, there was a reduction in this loss (-14,875.71 ha) that continued until 2021 (-8,275.04 ha).



Logging between 2000 and 2005 because in this period the significant economic aspects were related to the production of charcoal, which in 2002 was equivalent to 497,000 tons, accompanied by the sale of roundwood, which this year reached 1 million cubic meters (Redwan *et al.*, 2007). In 2008, there was intense surveillance, seizures and fines imposed on loggers (Piedade *et al.*, 2019). All these facts have been proven by obtaining data stored by the Real-Time Deforestation Detection System (DETER) identified that, between 08/2008 and 07/2009, there was a loss of Forest Class of approximately 3200 ha (INPE, 2009).

This can be explained by the introduction of aerospace technologies and adherence to the Green Municipalities Program (Young & Bakker, 2015). In 2010, the reduction can be explained by the increase in monitoring by federal, state, and municipal bodies (Pimentel, 2016), as well as the establishment of command-and-control mechanisms, such as the inclusion of the municipality of Paragominas on the List of Priority Municipalities (LMP) and Operation Arco de Fogo (OAF), as the number of sawmills there during this period contributed to the extraction of raw timber (Venceslau & Silva, 2021).

3.2 LAND USE

3.2.1 Urban Area

In relation to the expansion of the urban area, the evolution began in 2000 (1,331.56 ha); 2005 (1,464.13 ha); 2010 (1,742.6 ha); 2021 (2,026.87 ha), this is linked to population growth, since in 2000, Paragominas had 76,450 inhabitants and, in 2021, 115,538 inhabitants (IBGE, 2023). This causes a loss in arboreal ecological systems that induces negative changes in ecosystem services such as the rate of precipitation that acts on the water recharge of rivers, streams, among others (Oppong *et al.*, 2023).

3.2.2 Water

For the water class, the subdivisions characterized in MapBiomias were not considered, since the research focuses on the Uraim and Paragominas rivers, so the expression "surface waters" was chosen. In this respect, there has been a reduction in the surface area of water, since in 2000, this area was equivalent to 515.61 ha. In 2021, it was 307.7 ha (-207.91 ha), causing a loss in this class of 307.71 ha. As the Uraim River basin serves as a water source for the municipality, the annual rainfall is minimal: June to November \approx 23 mm. This could jeopardize the future supply to the area, leading to water shortages that could harm crops and livestock, as well as the local community.

3.2.3 Pasture and Agriculture

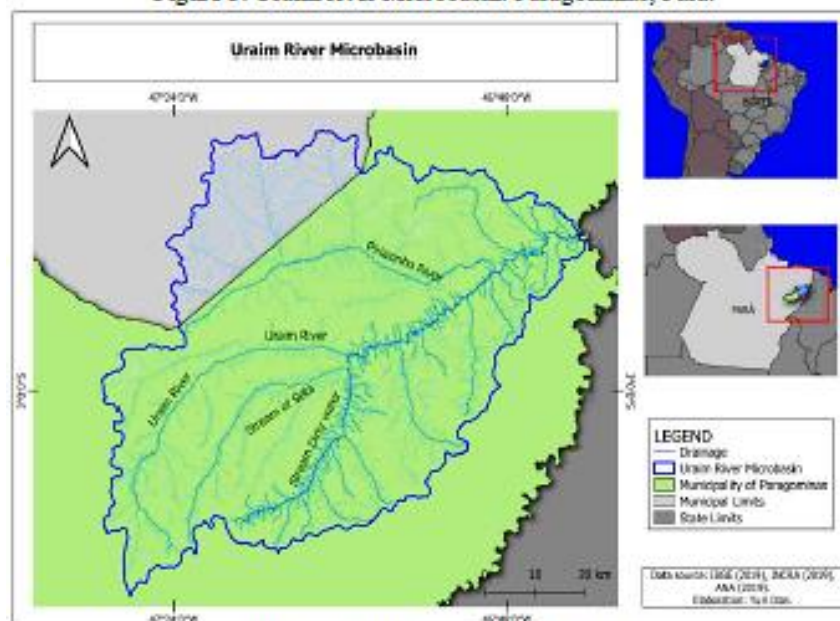
About Pasture Class, there was an upward trend between 2000 (163,853.94 ha) and 2005 (189,299.61 ha). However, in 2010 and 2021, there was a downward trend (187,561,86 ha and 125,229.9 ha, respectively). The decrease in this class in this period can be explained by the phenomenon of the so-called "dirty pasture" which was transformed into agricultural land for growing grains (Carvalho *et al.*, 2017). In the Agriculture Class, the data indicated that there was a slow growth trend between 2000 (1,342.43 ha) and 2005 (1,650.71 ha). In 2010 and 2021, the data indicated a very intense growth trend in this area: from 32,748.39 ha to 103,164.11 ha, respectively.

3.3 IMPACTS OF WATER RESOURCES

3.3.1 Watershed

Analysis of the data revealed that the hydrographic network of the Uraim River basin (Figure 3) has an average annual flow of 268,423 m³/h, which is effectively recharged by annual rainfall, which varies between 857 and 2,787 mm (Conceição *et al.*, 2020b; Santos & Picanço, 2008). This contribution is significant because the river serves as a source of water for the municipality of Paragominas, which SANEPAR is responsible for collecting, treating, and supplying to the community. The waters of this river reach 80% of the population of Paragominas (Conceição *et al.*, 2020a).

Figure 3. Uraim river Microbasin. Paragominas, Pará.



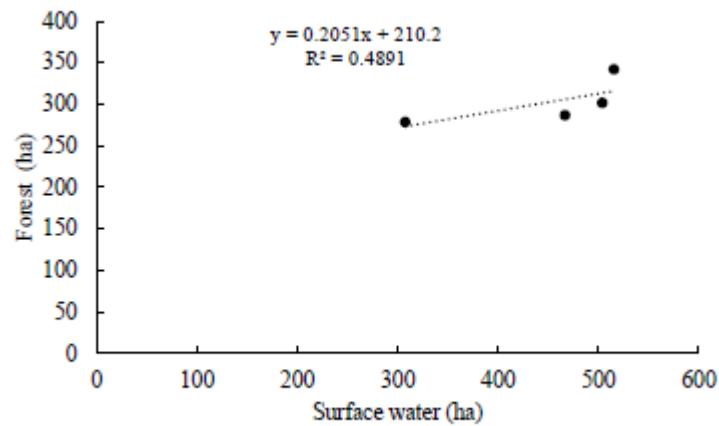
Elaboration: Dias, Y., NUPAD, 2023.

The Uraim River, whose length is equivalent to 202 km, in the region known as the "upper course" is flat in the geomorphological context, and near the springs, the relief becomes undulating with a maximum equal to 22% (Sousa, 2019). The Uraim River, whose length is equivalent to 202 km, in the region known as the "upper course" is flat in the geomorphological context, and near the springs, the relief becomes undulating with a maximum equal to 22% (Vieira *et al.*, 2012).

This contributes to the recharge of this watershed which, in Figure 3, is affected by 27 tributaries such as the Maritaca or Piriazinho river, the 54, Sete and Água Suja streams. However, it was not possible to identify the Paragominas stream, a right-bank tributary whose source is at Fazenda Cinderela. In 2012, this stream, in the urban stretch, was being used as an open-air dump. To get around this, the city council decided to create a leisure and landscaping area called Green Lake (Farias & Calandrino, 2018; Silva, 2023).

Despite these interventions, the loss of the Forest has contributed to a decrease in the surface water area (Figure 4), which may have occurred due to marginal erosion, the mass of soil being deposited in the channel of the Uraim and Paragominas rivers, which compromises the water quality of both rivers.

Figure 4 - Correlation between forest area and water area, Uraim river watershed, Paragominas, Para.

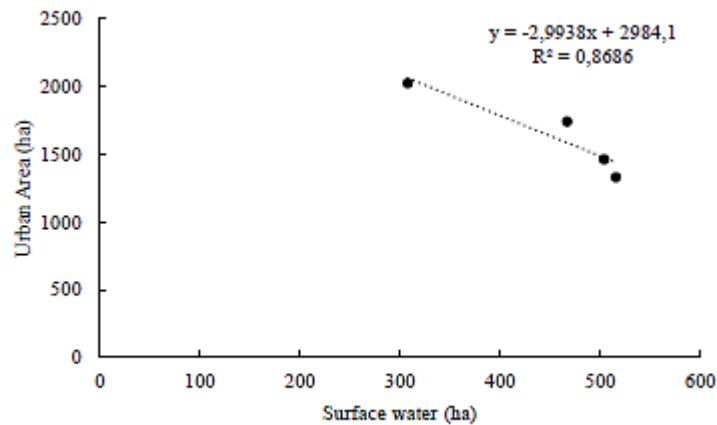


Source: Authors (2023).

Figure 4 shows that the value of the coefficient of determination ($R^2 = 0.4891 = 48.9\%$) indicated that the loss of forest directly influenced the loss of surface water area. The linear correlation coefficient ($r = 0.6994 = 69.9\%$) confirmed the direct proportional relationship between them, with $p\text{-value} = 0.3006$. In a study conducted in the Jacuri river basin, Amazonas, it was identified that the loss of forest caused a reduction in water area which, in 2020, represented only 0.52% of the total area of the river basin (Panza *et al.*, 2020).

This has contributed to the reduction in surface water areas which, due to the inadequate disposal of effluents generated by households located on the banks of the Paragominas and Uraim rivers, may have contributed to the change in water quality (Figure 5)

Figure 5 - Correlation between urban area and water area. Uraim river watershed, Paragominas, Pará.

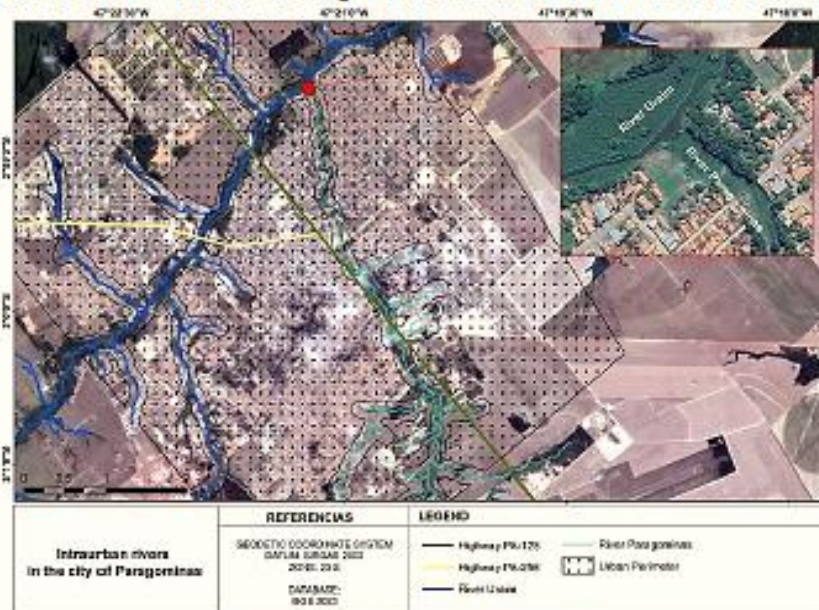


Source: Authors (2023).

Figure 5 shows that the coefficient of determination ($R^2 = 0.8686$; 86.9%), and the linear correlation coefficient ($r = 0.9320$; 93.2%) indicated that there is a positive inversely proportional relationship between them (p value = 0.680). This relationship alters water quality, since the urban area interferes with the run-off process, and this is a consequence of inappropriate land use and occupation. This was detected in a study conducted on the Ramadinha Canal, Campina Grande - Paraíba. In this canal, urbanization increased by 55%, which led to: a drop in water infiltration in the soil, consequently an increase in surface runoff, the dragging of contaminating particles, changes in water quality and an increase in the canal's flow (Alves *et al.*, 2020).

Another factor that contributes to affecting water quality in the Uraim river basin and its right-hand tributary, the Paragominas creek (Figure 6), is that both receive effluent from urban areas, as this municipality only has basic sanitation in 3.04% of the territorial area of this locality, where the presence of vegetation cover in this area is equivalent to 15.43%. As a result, this decrease in the Water Class has already caused flooding in 15.24% of the places where there is housing, which is an indicator of the loss of water resource quality (Pereira, 2021).

Figure 6 - Top view of the Uraim River and Paragominas river watershed in the urban area. Paragominas - Pará.



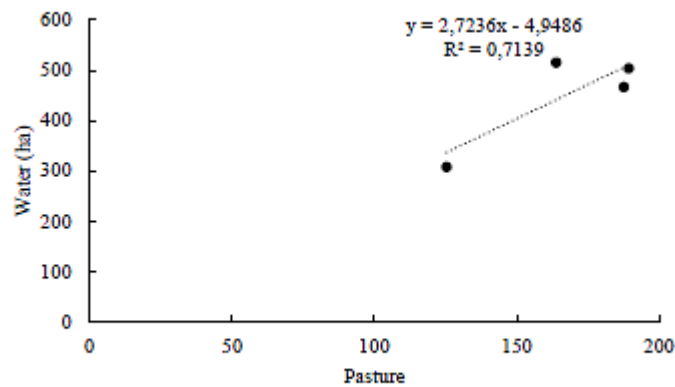
Elaborated by: Melo, E. E. P. (2023).

In a study conducted on the Sussuapara stream, in Palmas - Tocantins (Lima *et al.* 2017), the authors concluded that this stream has undergone changes in environmental aspects, with the advance of the urban area and, among the aspects affected, they cited the water factor. In general, the occupation of the banks of water bodies in urban areas causes damage to water quality, as was found in the research conducted on the Bolonha and Água Preta lakes in Belém - Pará (Vale *et al.*, 2021).

Pasture

The data obtained for the pasture-water correlation; the values obtained for the coefficient of determination ($R^2 = 0.7139$; 71.39%) indicated that pasture is a contributing factor to the loss of surface water areas in Paragominas (Figure 7).

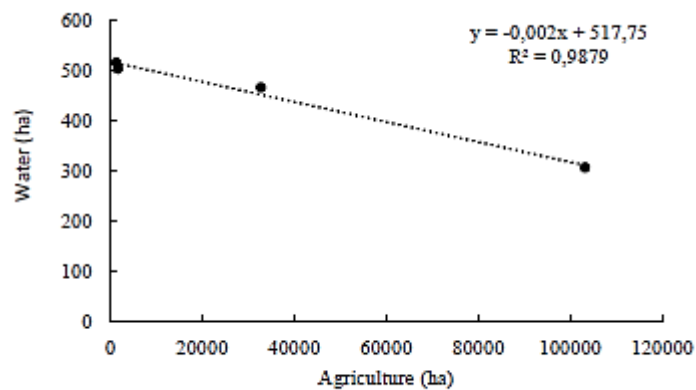
Figure 7 – Valor para o coeficiente de determinação para a correlação pastagem-água, em Paragominas, Pará.



Source: Authors (2023).

Another factor of value in this relationship was observed in the linear correlation coefficient ($r = 0.8449$; 84.49%), which confirms the positive and directly proportional correlation, i.e., if the pasture area grows, so does the loss of surface water area. The p-value (0.155; 15.5%) indicates that this correlation is significant and the growth of one variable directly affects the growth of the other. The relationship between the water and agriculture classes (Figure 8) over the period analyzed showed that the two are inversely proportional and strongly correlated ($R^2 = 0.9879$; 98.79%).

Figure 8 - Correlation between water and agriculture classes, Uraim river basin, Paragominas, Pará.



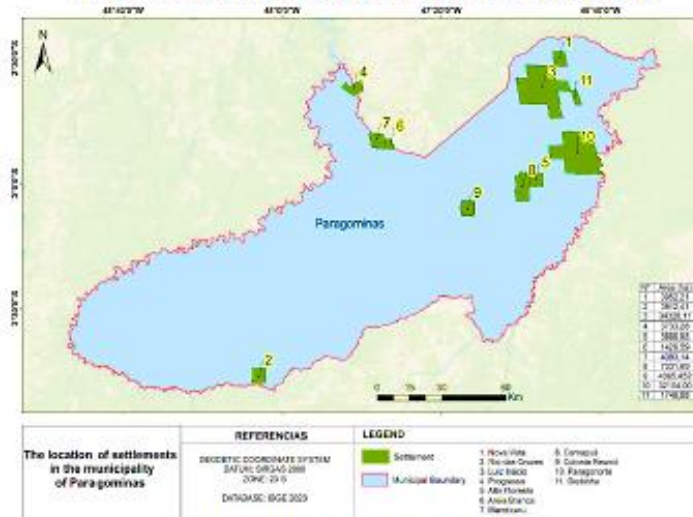
Source: Authors (2023).

In Figure 8, the value of the linear correlation coefficient (r) was negative (-0.9940; 99.4%; p = 0.0061), but the p-value indicates that there are other variables that have a greater effect on water resources, so the expansion of agriculture may be a factor that has caused a decrease in the supply and quality of water. When rural properties expand their boundaries, they act on the sites where rivers and streams originate. In general, these springs are located in places where the use of this natural resource is high, especially in the agricultural sector (Colleti, 2022). This compromises water quality and, in the state of Pará, this occurs in regions such as the southeast of the state, in the municipality of Paragominas.

3.4 LAND USE AND OCCUPATION - PA's

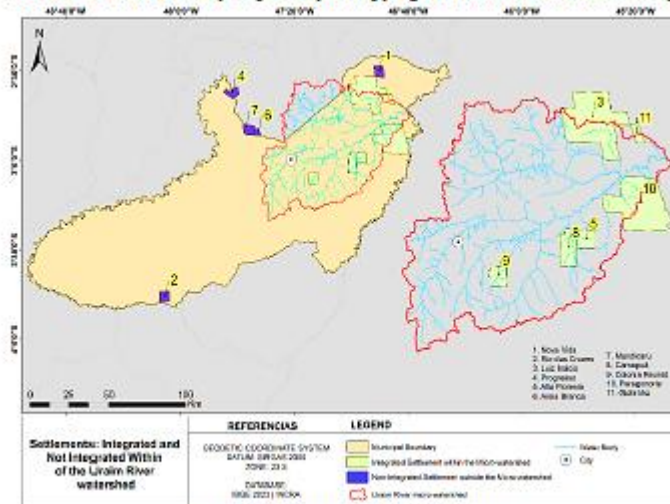
There are 11 settlements occupying 101,285.01 ha of the total area of the municipality. The Luis Inácio PA occupies 33.9%, or 34328.11 ha (Figure 9a). Overlaying the maps showed that, of the total number of PA's identified, three are entirely in the area of the Uraim River Basin, as well as three others which also have parts of their areas in this river basin (Figure 9b).

Figure 9a - Settlements registered with INCRA. Paragominas, Pará.



Elaborated by: Melo, E. E. P. (2023).

Figure 9b - PA's whose areas are fully or partially occupying the BH Rio Uraim area. Paragominas, Pará.



Elaborated by: Melo, E. E. P. (2023).

With regard to the Paragonorte Settlement Project, it came into being in 1988, after settlers who lived in the "Alto Guamá" Indigenous reserve were resettled in the area expropriated from the Swift Farm. In these two places, deforestation and cattle raising were intense and inadequate until 1997. Other colonies: Uraim Colony, founded in 1965 and recognized since 1969 by the State Secretariat for the Environment and Sustainability - SEMAS, and by Municipal Law No. 736 (Paragominas, 2010), where approximately 309 families are settled, some of whom ($n = 60.0$; 19.4%) practice family farming, in an area of 269,184.10 m².

Other settlements are located in the geographical area of this city. In addition to the PA's show in figure 9a, there are 25 more, namely: Água Suja, Auto Coracy, Baixo Uraim, Cachoeira, CAIP (483 families), Colônia Nazaré, Colônia Providência, Escadinha, Faixa 5, Faixa do Aprisco, Faixa Tauari, Gleba 22, Gleba 28, Glebinha, Km 15, Nova Formosa, Nova Jerusalém, Peracchi, São Lucas, São Sebastião, Vila Conceição (Piriá), Vila Nova (224 families), Vila Oriente, Vila São João (204), Vila União (260 families).

4 DISCUSSIONS

Deforestation in Paragominas has links with the emergence of the city and with the desire to connect the north to the south of Brazil, via BR - 010, in 1959, since then, is shown on an crimes against flora and deforestation in Paragominas, indicated that between 2010 and 2017, there was a loss of vegetation cover from 8,605 km² to 8,773 km², where the clean pasture class accounted for 47% of this total. In the research conducted by Sousa et al. (2017), on land use and coverage, the authors found a reduction in forest suppression by 4.54% in 2021, contrasting with the expansion of the agricultural area, this year, to 73,638 ha.

In relation to the areas occupied after deforestation, in the city of Paragominas, they are presented under three definitions: pastures, agriculture, and exposed soils. Ribeiro et al. (2017) evidenced such definitions, when they conducted studies in the PPA areas of the Uraim river basin. They concluded that land use and pastureland were prevalent in this basin because they occupy 27% of the basin's area. In the research conducted by Cardoso et al. (2017), the predominance of clean pasture areas ranges from 6,617.5km² to 2,295.7 km².

As for the first justification, cattle raising was the biggest driver of deforestation in this city. About this Galvão et al. (2013), synthesized that between 1968 and 1973, the herd in this city suffered an increase of 420% (from 19,627 heads to 81,838 heads). This type of land use was consolidated in 1992 when the city had approximately 600,000 heads. However, due to the introduction of new economic activities in the city (e.g., logging), the predominance of livestock was reduced, so much so that, in 2017, the cattle herd consisted of 419,430 heads. More recent study by Castro et al. (2021), identified that in the community called Camper Agroflorestral do Pará (CAIP), which now houses 400 families, of which 360 ($n = 90\%$) families, has as an economic priority, the creation of cattle, of the type "extensive livestock (continuous and rotary grazing)". This place is included in the Master Plan of the City (Paragominas, 2005), in article 14, as "neighborhood unit - NU" The values for the averages of the areas occupied by this economic activity are 248 km².

In the research conducted by Chaves et al. (2018) about the economy of productive areas in the city of Paragominas, it was proven that livestock (dairy) is still active in 143 properties analyzed, in which the complementary activity is logged in 13 of them. Regarding this extraction, the data analyzed indicated that it began in 1995:

logging began to predominate in the economic sector of Paragominas, and reached its peak in 2005, with 137 sawmills, in addition to 238 industries linked to the logging sector. As for this economic vein in Paragominas, Pimentel (2016), conducted a geosystemic analysis and concludes that timber stocks are scarce, in addition to the rigor of inspection, in the face of the change in legislation¹.

Regarding family farming, the city has 15 agricultural communities. Among them, the Paragonorte Settlement Project (SP), whose area is approximately 0.24 km². In this area, we have: CAIP (called the Headquarters Village), in addition to Vila União and Vila Nova. In the study conducted by Moura and Rocha (2016), in this SP, they concluded that the use and occupation of the soil for agricultural production occurs in the form of fields with permanent crops. Souza and Silva (2020) identified that, in this settlement, deforestation for the commercialization of wood decimated what was left of the devastated forest until 1997. Then, in this settlement, the practice of slash and burn" began, for agricultural production.

In the study conducted by Rocha and Maia (2018), in another SP, called "Colônia do Uraim" whose 40 families established there, have lots of land smaller than one ha, they concluded that only 24% make use of fire to clean the property. The use for mixed economic activities (livestock and family farming), is another destination for the soil, whose areas, for the first activity, has an average value equal to 248 km²; and for the second, 41 km², which totals 323 km² (n = 1.7% of occupied area in the city = 19,428.30 km²). About these activities in these communities, Bessa et al. (2019), carried out a study on family farming in Paragominas, and concluded in the communities of Nazaré (48 families) and São Sebastião (60 families), then called "traditional riverine", agricultural activities are focused on the cultivation of corn, colony beans, rice, and cassava, in addition to practicing logging.

For the relationship of the use and occupation of the soil with the Uraim rivers, the data indicated that the Uraim Colony is located on the left bank of the first, in the upstream-downstream direction, the use of synthetic products to combat crop pests, and frequent. As for this action, Rocha, and Maia (2018), in a survey conducted in this colony, concluded that most farmers (n = 24.0; 60.0%) use poison (agricultural defensive) to combat pests and diseases that affect their crops, as well as Nitrogen, Phosphorus and Potassium (NPK).

In the study conducted by Santos and Silva (2020), in Paragominas, to verify existing agroforestry systems, they identified that most of them (n = 14.0; 45.0%) use pesticides to control pests. In the rainy season, phosphorus is easily carried to the bed of the Uraim River and with this, it can assist in bioaccumulation, which is harmful to vertebrates and benthic invertebrates, as this river is the source of the city, can cause organic disturbances in the community (bone pain due to hypophosphate).

In the studies carried out by Mendonça (2018), Santos et al. (2021), and Siede, Hermann and Tissot-Squalli (2018), about the toxic potential of glyphosate (herbicide) and by Bester *et al.* (2020) and Freisthler *et al.* (2022) on dichlorophenoxyacetic acid (2-4 D), used as agricultural pesticides in soybean and corn crops, they concluded that, despite the low leaching potential, the two present high adsorption to the soil, and this facilitates infiltration and percolation and, indirectly, in the recharge via the water table, contaminates the waters of the rivers. In the case of mancozeb, the leaching rate is high. As all of them are in use in the family farming communities in Paragominas, the waters of the Uraim River may contain indicators of these substances.

¹ Provisional Measure No. 1,511, of July 25, 1996, which changed the percentage of the obligation in relation to the mandatory vegetation cover from 50% to 80%.

Such facts were proven in the research carried out by Farias and Calandrino (2018), with the application of georeferencing and application of tools such as Normalized Difference Vegetation Index and Green Areas Index, whose acronyms, in English, are, respectively, NDVI and IAV, proved the growth of urbanization and a reduction in vegetation coverage, both sparse (2005 = 31%; 2017 = 13%) and dense (2005 = 14%; 2017 = 7%), especially in Green Lake, that is, Igarapé Paragominas river.

These authors also indicated that the current values for the IAV are still below that recommended by the Brazilian Society of Urban Afforestation, which is equivalent to 15 m²/inhabit. SECTION 1996: However, the significance for "urbanized area" in relation to deforestation was similar in the two decades analyzed (2000- 2010, $p = 0.8834$; 2010-202-, $p = 0.8971$). The Igarapé Paragominas, located in the urbanized area" of Paragominas, due to the loss/replacement of the riparian forest (PPA) and modification in its physical structure (meander), in 2018, suffered an overflow.

In the research conducted by Rodrigues et al. (2020), in the Paragominas igarapé basin, in the city of the same name, the data obtained and analyzed were conclusive regarding the increase in surface runoff in relation to the extreme rainfall that year. They also recommend that the urban growth of Paragominas be reviewed. This corroborates the research conducted in Norway by Jost et al. (2012) who analyzed the relationship of vegetation coverage cover.

Regarding the water supply in the Uraim colony, Guimarães et al. (2020), conducted a survey on the socioeconomic profile of the farmers who reside in it, and concluded that 58%, is supplied by water from artesian wells. Another conclusion was the expansion of agricultural production. It cannot be conducted in areas farther from the riverbank because the "land is dry", so irrigation is ineffective. They also found that sanitary sewage is classified as reasonable ($n = 25.0\%$) and poor ($n = 17.0\%$). In the research conducted by Souza (2018), this author observed the existence of dams (two) that, according to the owners, flow from the Uraim River. So, there is a great possibility that the Uraim River is being used as a recipient of effluents, both domestic and agricultural production, which can change the quality of the water.

On the left bank of the Uraim River, upstream-downstream, in an area equivalent to 1,090, 84 km² ($n = 5.7\%$ of the total area of the city), 15 family farming communities are allocated, which still operate under the slash and burn process, and where three crops are more frequent: rice, beans, cassava. In addition to them, are also present: corn and black pepper. In this regard, the data obtained indicated that since 2016, the planting of grains, especially soy [(*Glycine max* (L.) Merrill], Fabales Family, has been replacing pasture areas (8% to 25%) and, in 2018, the planted area reached 125,000 ha. For cattle watering, local cattle ranchers use the Uraim River as a water source, from open clearings, that is, suppression of riparian forest (PPA).

These actions have already been the objects of research by Castro et al. (2021), when they analyzed the productivity of family livestock at CAIP, in Paragominas - Pará. The authors concluded that, of the 32 cattle raiser families in this place, 64% use the river itself as a cattle watering place; 15.0 ($n = 30.0\%$), use dams that, in most cases, are made from deviations caused in the meanders of the water bodies, and three ($n = 6\%$) use wells. It is verified that the water quality of the Uraim River can be altered in several ways: by the deforestation of the riparian forest, by the contamination of the feces and urine of the cattle, and by infiltrating the soil, it can be captured in the wells and cause a re-infestation in the herd. Not only is the main river of the Uraim micro-basin being altered. The tributaries named Igarapé 54 (02°52'43" and 03°04'14" S, and the longitudes 47°15'08" and 47°31'14" W), Igarapé Sete (Latitudes 02° 56'23" and

03°17'09"S; longitudes: 47°07'35" and 47°23'35"W), in addition to Parariquara, also undergo changes.

The data obtained indicated that the damage caused by the marginal vegetation in the watersheds is the loss of water quality and decrease in depth. In this regard, Cantuário and Oliveira (2020), in the research they carried out on deforestation and PPA legislation in the city of Paragominas, concluded that these effects have as their main cause, the expansion of human occupation has decreased the presence of riparian forest and increased the number of civil constructions for housing and/or trade, or the use and occupation of land for agricultural production and livestock. The analysis of the data also indicated that the water damage is broader because one of the sources of the Uraim River, located inside a private property, 42.2 km away from the already urbanized area of Paragominas, which should be protected, is in a state of "disturbance" (Figure 10).

Figure 10. Spring 1 of the Uraim River, on a private property. Paragominas, Pará.



Source: Santos and Picanço (2008).

Regarding this situation, Santos and Picanço (2008) carried out a study to restore the forest ecosystem of this source and classified the state of this source as "disturbed", due to vegetation cover, and the existence of a pasture area less than 50 m from it, with "protective" vegetation made by Brachiaria grass (*Brachiaria brizantha* cv. Mandacaru, Host ex. A. Rich) Stapf, Poaceae family, and kicuío grass (*Brachiaria humidicola* Rendel) Schwickerdt², belonging to the same family. This is a stimulus for the spring area to be trampled by cattle when watering. In the study on the marginal reforestation of the Uraim River, on a rural property Uraim Colony (Figure 11). (Borges *et al.* (2017), were informed by the owner that this river no longer has the same capacity to "fill as it did 15 years ago".

Figure 11. Marginal coverage of the river on private property. Colony of Uraim, Paragominas-Pará.



Source: Borges et al. (2018)

² Selffert, N. F. Forage grasses of the genus *Brachiaria*. Campo Grande: Embrapa, 1980. Technical Circular No. 1.

The suppression of riparian forest, or the non-preservation of the original, caused the loss of the retention capacity of the arboreal moisture to perform photosynthesis, and this interferes with evaporation and, consequently, the hydrological cycle. So, the lower the PRP rate, the harder it is to recharge the Uraim River. This absence of arboreal vegetation of the riparian forest, either in the form of a canopy or canopy, in the rainy seasonal period, in the Uraim river, and depending on the precipitation rate, pH, tends to change. In the study conducted by Nascimento et al. (2020) in the Uraim River, in this period, the value found by them (pH: P1 = 4,15; P2 = 4,91) was below that stipulated for Class II water, to which the Uraim River belongs. It is known that other variables also influence, such as soil (Dystrophic Yellow Latosol) or effluent inlet.

Therefore, a more frequent and more accurate control of the quality of the water is necessary, before and after plant suppression. Another important fact is the verification that the values found for pH are inserted in the characteristic range of the waters of the Amazon: 4.0 to 7.8, and for the latter value, the aquatic environment is already characterized as "marine" (SILVA et al., 2008).

5 CONCLUSIONS

In Paragominas, geospatial analysis has shown that forest degradation and marginal suppression in the Paragominas and Uraim rivers have been replaced by economic activities, such as family farming, in agricultural settlements and rural communities along the banks of the Uraim River, upstream-downstream. Due to the use of pesticides and the watering of livestock inside the water body after the suppression of riparian forest, it is necessary to frequently monitor changes in the water quality of the Uraim River, which is the water supply source for the collection, treatment, distribution, and supply by SANEPAR in the region.

In the urban area, the Igarapé Paragominas had its riparian forest degraded or replaced by species such as palm trees, resulting in an adequate scenic landscape, but without the ecosystem services provided by the natural riparian forest, especially in this area. The river empties into the Uraim River, right bank, upstream-downstream. However, the volume of academic research in relation to the Igarapé Paragominas is much smaller, which indicates the lack of information on deforestation, land use and occupation, and water quality. In addition, this river became a receiving body of effluents due to the scarcity of the drainage network for their collection. Therefore, this body of water may present changes that compromise the quality of the water and, if not diluted, may be flowing into the Uraim River.

The data presented here can be used for comparisons with future research to verify the trend of environmental quality, maintenance of the riparian forest, forests, use and occupation of the soil, in addition to the water resources, regarding evolution, involution.

REFERENCES

ALVES, L. G. F.; SANTOS, B. L. F.; VEIGA, M. E. B.; GALVAO, C. O.; MACHADO, E. C. M. Impacto da urbanização no escoamento superficial em bacia ocupada por assentamento precário em Campina Grande. *In: ENCONTRO NACIONAL DE ÁGUAS URBANAS*, 13. 2020. Rio Grande do Sul. **Anais eletrônicos**. Disponível em: <https://files.abrhidro.org.br/Eventos/Trabalhos/131/XIIIENAU-IISSRU0104-1-20200925-193307.pdf>. Acesso em 30 jul. 2023.

ALVES, L. W. R.; CARVALHO, E. J. M.; SILVA, L. G. T. **Diagnóstico agrícola do município de Paragominas, PA**. Belém: Embrapa Amazônia Oriental, 2014. Boletim de Pesquisa e Desenvolvimento, 91.

ARAÚJO, D. L.; ANDRADE, R. F. Qualidade Físico-Química e Microbiológica da Água Utilizada em Bebedouros de Instituições de Ensino no Brasil: Revisão Sistemática da Literatura. **Brazilian Journal of Health Review**, Curitiba, v. 3, n. 4, p.7301-7324, 2020.

BESSA, M. S. C.; FERREIRA, J. N.; COUDEL, E. S.; DILSA, F. E.; ROMAGNOLI, F. Motivação de agricultores familiares para participarem de ações de recuperação florestal em Paragominas, Pará. **Agricultura Familiar: pesquisa, formação e desenvolvimento**, v. 13, n.º 1, p.09-27, 2019.

BESTER, A. U.; MELLO, M. O. B.; MELLO, M. B.; CARVALHO, N. L.; PEREIRA, E. A.; LUCCHESI, O. A. Os efeitos das moléculas de 2,4d e o tebuconazol sobre o meio ambiente e os organismos não alvos. **Revista Monografias Ambientais**, v. 19, e2, 2020.

BORGES, L. S. MATOS JÚNIOR. F. T.; BIRANI, S. M.; SILVA, A. J.; SOUSA, V. Q. Iniciativa de recuperação da mata ciliar às margens do rio Uraim no município de Paragominas -PA. **Cadernos de Agroecologia**, v. 13, .n.º 1, 2017.

BRASIL. **Decreto-Lei n.º 1.110**, de 9 de julho de 1970. Cria o Instituto Nacional de Colonização e Reforma Agrária (INCRA), extingue o Instituto Brasileiro de Reforma Agrária, o Instituto Nacional de Desenvolvimento Agrário e o Grupo Executivo da Reforma Agrária e dá outras providências. Disponível em: https://www.planalto.gov.br/ccivil_03/decreto-lei/1965-1988/del1110.htm#:~:text=DECRETO%2DLEI%20N%C2%BA%201.110%2C%20DE%209%20DE%20JULHO%20DE%201970.&text=Cria%20o%20Instituto%20Nacional%20de,Agr%C3%A1ria%20e%20d%C3%A1%20outras%20provid%C3%AAsncias.. Acessado em: 29 mar. 2023.

BRASIL. **Lei n.º 6.746**, de 10 de dezembro de 1979. Altera o disposto nos arts. 49 e 50 da Lei nº 4.504, de 30 de novembro de 1964 (Estatuto da Terra), e dá outras providências. Disponível em: https://www.planalto.gov.br/ccivil_03/leis/1970-1979/l6746.htm. Acesso em: 20 mai. 2023.

CARDOSO, R. S.; BELLUZZO, A. P.; SILVA, R. N. P.; SILVA, L. G. T. VENTURIERI, A.; CAMPOS, A. G. S.; VALENTE, M. A. **Relações entre a paisagem e a dinâmica de uso da terra no município de Paragominas -PA. Uso de produtos SRTM e dados do TerraClass no mapeamento, distribuição e conversões entre sistemas de pecuária e agricultura anual**. 2017. São Paulo. Disponível em: <https://www.embrapa.br/busca-de-publicacoes/-/publicacao/1072668/relacoes-entre-a-paisagem-e-a-dinamica-de-uso-da-terra-no-municipio-de-paragominas-pa-uso-de-produtos-srtm-e-dados-do-terraclass-no-mapeamento-distribuicao-e-conversoes-entre-sistemas-de-pecuaria-e-agricultura-anual>

CANTUÁRIO, V. A. P.; OLIVEIRA, F. S. Entre o desmatamento e a legislação: questões a serem consideradas sobre a situação recente das áreas de preservação permanente de Paragominas-PA. **Revista Eletrônica de Humanidades**, v. 13, n.º 2, p. 373-398, 2020.

CARVALHO, F. C. *et al.* Dinâmica de uso da terra, no setor agropecuário, em Paragominas – PA, **Agroecossistemas**, v. 9, n. 2, p. 148-163, 2017.

CASTRO, D. D. S.; BARBOSA, J. B.; OLIVEIRA, C. D. S.; AQUINO, R. A.; SILVA, A. S. F.; MELO, W. O.; RIBEIRO, M. S. M. Caracterização socioeconômica e produtiva da pecuária familiar na comunidade CAIP, Paragominas - PA. In: SANTOS, T. R. **Engenharia agrônoma: ambientes agrícolas e seus campos de atuação**. Ponta Grossa: Atena, 2021. cap. 12, p. 139-153.

CHAVES, L. M. L.; SCHULER, A. E. CHAVES, C. L. Avaliação da vulnerabilidade natural do aquífero em bacia de pequeno porte do rio Uraim, Paragominas - PA. In: . SIMPÓSIO BRASILEIRO DE RECURSOS HÍDRICOS. 17. 2007. São Paulo. **Anais eletrônicos**. Disponível em: <https://anais.abrhydro.org.br/jobs.php?Event=151>. Acesso em: 09 set. 2022.

CHAVES, M.V L.; PARENTE, Y. Y.; TANCREDI, N. S. H.;TAVARES, F. B.; SIMÕES, P. S. Rentabilidade econômica de propriedades rurais em Paragominas (PA) com o suporte de geoprocessamento. **Revista Ibero-Americana de Ciências Ambientais**, v.9, n.º 6, p. 199-212, 2018.

COELHO, G. L. S.; COSTA, G. L. O. Processo histórico do assentamento Santo Antônio em Porto Nacional – TO: uma leitura histórica através da educação do campo. **Revista Brasileira de Educação do Campo**, v. 7, 2022.

COLETTI, T. Ninguém diga “desta água não beberei”: produção agropecuária e contaminação hídrica no oeste catarinense, Brasil. **Cadernos de Saúde Pública**, v. 38, n. 4,2022.

CONCEIÇÃO, M. M. M.; SOUZA, R. R. N.; SILVA. A. C. S.; MACHADO, N. I.; CARNEIRO, C. C.; GUEDES, F. L.; SILVA, N. S.; SILVA, M. S; LIMA, A. C. S.; TAVARES, L. S.; SOUZA, G. B.; MARTINS, I. V. M.; RIBEIRO, T. S.; SILVA, M. P.; SILVA, A. S. F.; A lógica Fuzzy no estudo da qualidade da água do rio Uraim, Paragominas-PA. **Brazilian Journal of Development**, v.6, n.º 6, p. 38575-38888, 2020a.

CONCEIÇÃO, M. M. M.; SOUZA, R. R. N.; SILVA, A. C. S.; MOURÃO, F. V.; PEREIRA JÚNIOR, A. Políticas e legislação: avaliação no manejo de uma microbacia hidrográfica. **Revista Gestão & Sustentabilidade Ambiental**, v. 9, n.º4, p. 631-652, 2020b.

CREPANI, E; MEDEIROS, J. S.; FILHO, P. H.; FLORENZANO, T. G.; DUARTE, V.; BARBOSA, C. C. F. **Sensoriamento remoto e geoprocessamento aplicados ao zoneamento ecológico-econômico e ao ordenamento territorial**. São José dos Campos : INPE, 2001.

DIAS-FILHO, M. B. **Formação e Manejo de Pastagens**. Belém: EMBRAPA. Comunicado Técnico, 235, 2012.

ELLIS, E.; MONTERO, J. A. R.; GÓMEZ, I. U H. Deforestation process in the State of Quintana Roo, Mexico: the role of land use and community forestry. **Tropical Conservation Science**, v. 10, p. 1-12, 2017.

FARIAS, C. S.; CALANDRINO, C. P. **O município verde e suas áreas urbanas não tão verdes: avaliação qualitativa e quantitativa das principais áreas verdes urbanas de Paragominas – PA**. 2018. Monografia (Bacharel em Engenharia Florestal) – Universidade Federal Rural da Amazônia, Paragominas, 2018.

FREISTHIER, M.; ROBBINS, C. R.; BENBROOK, C. M.; YOUNG H. E.; HAAS, D. M.; WINCHESTER, P. D.; PERRY, M. Association between increasing agricultural use of 2,4-D and population biomarkers of exposure: finding from the National Health and Nutrition Examination Survey, 2001-2014. **Environmental Health**, v. 21, n.º 23, 2022.

GALVÃO, I. M. F. **Da fronteira à sustentabilidade? O caso de Paragominas-PA. 2013**. Dissertação (Mestrado em Gestão dos Recursos Naturais e Desenvolvimento Local na Amazônia) - Universidade Federal do Pará, Belém, 2013.

GUIA, A. P. O. M.; VEIGA, J. B.; LUDOVINO, R. M. R.; SIMÃO NETO, M.; TOURRAND, J-F. **Caracterização dos sistemas de produção da agricultura familiar de Paragominas-Pa: a pecuária e a proposta de desenvolvimento**. Belém: Embrapa Oriental, 1999. Documento 5.

GUIMARÃES, C. C. V.; BORGES, L. S.; CUZZUOL, L. B.; AVIZ, R. O.; SILVA, M; J. S.; SANTOS, T. Perfil socioeconômico e aspectos produtivos de agricultores familiares da Colônia do Uraim, Paragominas, Pará. **Revista de Ciências Agroambientais**, v. 18, n.º 2, p.88-98, 2020.

HASAN, A. **evaluation de la dégradation des forêts primaires par télédétection dans un espace de front pionnier consolidé d'Amazonia orientale (Paragominas)**. 2019. These (Doctorat an Sociétés, Temps, Territoires) – Le Mans Université, France, 2019.

IBGE. Instituto Brasileiro de Geografia e Estatística. **Proposta metodológica para classificação dos espaços do rural, do urbano e da natureza no Brasil**. Rio de Janeiro: IBGE, 2023.

INCRA. Instituto Nacional de Colonização e Reforma Agrária. **Assentamentos**. 2020. Disponível em: <https://www.gov.br/incra/pt-br/assuntos/reforma-agraria/assentamentos>. Acessado em: 20 mai. 2023.

INPE. Instituto Nacional de Pesquisas Espaciais. **Avaliação dos dados de desmatamento do município de Paragominas/PA**. Relatório Técnico. 2009. Disponível em: NT_paragominas_0809_deter (inpe.br). Acesso em: 13, mar. 2023.

JOST, G. et al. A hillslope scale comparison of tree species influence on soil moisture dynamics and runoff processes during intense rainfall. **Journal of Hydrology**, v. 420, n. 2, p. 112-124, 2012.

JAMAL, T.; NASEER, S.; HASSAN, S. S.; BATOOL, H.; MAHMOOD, R.; NAZ, A.; BUTT, A.; TANVER, U; KAAUKAB, I. S.; ALVI, S.; AHMEAD, J.; AKHTAR, A.; JAVED, A. ALI, A. Appraisal of deforestation in Murree through open-source satellite imagery. **Scientific Research Publishing**, n.º 7, p. 61-70, 2018.

MENDONÇA, C. F. R. **Determinação de glifosato e AMPA nas águas superficiais da bacia do Paraná 2**. 2018. Dissertação (Mestrado em Química) – Universidade Estadual Paulista “Júlio de Mesquita Filho”. 2018.

MERCIER, A.; BETBEDER, J.; RUMIANO, F.; BAUDRY, J.; GOND, V.; BLANC, L. BOURGOIN, C.; CORNU, G.; CIUDAD, C.; MARCHAMALO, M.; POCCARD-CHAPUIS, R.; HUBERT-MOY, L. Evaluation os Sentinel-1 and 2 tine series for land cover classification of forest-agriculture mosaics in temperate and tropical landscape. **Remote Sensing**, n.º 11, 2019.

MESSIAS, C. G.; AMORIN, R. R. Distribuição espacial do desmatamento e o uso da terra na bacia hidrográfica do rio das Velhas – MG. In: CONGRESSO BRASILEIRO DE ORGANIZAÇÃO DO ESPAÇO. 3. 2021. São Paulo. **Anais eletrônicos**. P. 286-301. Disponível em: [e63aa8_e73aa929c5334f4b968cba1d44c2470e.pdf](https://filesusr.com/e63aa8_e73aa929c5334f4b968cba1d44c2470e.pdf) (filesusr.com). Acesso em 30 mar. 2023.

MOURA, R. L.; ROCHA, V. W. P. “**Da conquista da terra, ao sistema de produção e comercialização: dados relevantes do PA Paragonorte, Paragominas, Pará**”. 2016. Dissertação (Bacharelado em Engenharia Agrônômica) - Universidade Federal Rural da Amazônia, Paragominas, 2016.

MUNEME, A.; HALL, D. Factors influencing perceptions of private water quality in North America: a systematic review. **Systematic Reviews**, v. 8, n.º 111, 2019.

NASCIMENTO, J. M. H.; FARIAS, T. L.; SILVA, M. S.; MIRANDA, L. A. S.; MOURÃO, F. V.; CORRÊA, G. M. Análise preliminar da qualidade da água de um corpo hídrico em Paragominas, PA. **Brazilian Journal of Development**, v. 3, n.º 3, p. 2272-2281, 2020.

NEVES, M. N. B.; CUNHA, B. J. C.; TEIXEIRA, T. D. P.; PANTOJA, A. S.; AGRIPINO, L. M.; ISHIHARA, J. H. Análise temporal quali-quantitativa da água em relação à processo de desativação de barramento de água na microbacia do Igarapé Parariquara, no município de Paragominas-PA. In: Congresso Brasileiro de Engenharia e Ambiental. 17. 2022. Minas Gerais. **Anais eletrônicos**. Disponível em: <https://schenautomacao.com.br/cbge2022/anais/trabalhos.php>. Acesso 30 nov. 2022.

OPPONG, J.; NAMWAMBA, J. B.; TWUMASI, Y. A.; ASARE-ANSAH, A. B.; AKINRINWOYWC.; ANTWI, R.; OSIMBO, B. M.; LOH, P.; FRIMPONG, D. B.; APRAKU, C.; ATAYI, J.; AHOMA, G.; ANNAN, J. Urbanization and urban forest loss: a spatial analisys of five metropolitan district in Ghana. **Geology, Ecology, and Landscape**, 2023. Disponível em: <https://doi.org/10.1080/24749508.2023.2202439>

PANZA, M. R.; DONEGÁ, M. V. B.; PACHECO, F. M. P.; NAGÃO, E. O.; HARA, F. A. S.; CAVALHEIRO, W. C. S.; VENDRUSCOLO, J. Características da paisagem para ameno dos recursos naturais na microbacia do rio Jacuri, Amazônia Ocidental, Brasil. **Brazilian Journal of Development**, v.6, n.º 12, p. 101532-101558, 2020.

PARÁ. **Decreto n.º 16,84**, de 29 de junho de 2021. Estabelece o valor da terra nua (VTN) para regularização fundiária onerosa de terras públicas do Estado do Pará, em áreas rurais. Disponível em: <https://www.legisweb.com.br/legislacao/?id=416495>. Acessado em: 23 mar. 2023.

PARAGOMINAS. **Lei n.º 597**, de 25 de novembro de 2005. Institui o Plano Diretor de Desenvolvimento Urbano do Município de Paragominas e dá outras providências. Disponível em: <https://paragominas.pa.gov.br/wp-content/uploads/2020/12/7-LEI-MUNICIPAL-Nº.-597.2006-PLANO-DIRETOR-DE-DESENVOLVIMENTO-URBANO-PDDU.pdf>. Acesso em: 09 set. 2022.

PARAGOMINAS, **Lei municipal n.º 736**, de 23 de setembro de 2010. Autoriza a aprovação de loteamento urbano denominado Vila da Colônia do Uraim e dá outras providências. Disponível em: <https://camaraparagominas.pa.gov.br/wp-content/uploads/2019/07/LEI-Nº-736.2010-AUTORIZA-A-APROVAÇÃO-DE-LOTEAMENTO-URBANO-DENOMINADO-VILA-DA-COLÔNIA-DO-URIAM.pdf>, Acesso em: 09 set. 2022.

PEREIRA, A. S.; SHITSUKA, D. M.; PARREIRA, F. J.; SHITSUKA, R. **Metodologia da Pesquisa Científica**. Santa Maria: UFSM, NTE, 2018.

PEREIRA, L. C. **Análise da qualidade ambiental a partir de indicadores ambientais na área urbana de Paragominas**. 2021. Dissertação (Mestrado em Geografia) – Universidade Federal do Pará, Belém, 2021.

PEREIRA, L. C.; CORRÊA, D. L.; SILVA, C. C. R.; LIMA, M. J. A.; SOUZA, R. R. N.; SILVA, A. C. S. Estudo das formas de ocupação das APPs de partes do rio Uraim, Paragominas -PA. In: SIMPÓSIO BRASILEIRO DE ENGENHARIA AMBIENTAL. FÓRUM LATINO-AMERICANO DE ENGENHARIA E SUSTENTABILIDADE. 14. 2016. Distrito Federal. **Anais eletrônicos**. Disponível em: <https://www.proceedings.blucher.com.br/article-list/eneeamb2016-273/list#article>. Acesso em 10 set. 2022.

PETER, Y.; REUBEN, I.; BULUS, E. The application of remote sensing and geographic information system (SIG) for monitoring deforestation in South-West Nigeria. **Journal of Environmental Issues and Agriculture and Development Countries**, v, 4, n, 1, p. 6-11, 2012.

PIEIDADE, G. S. A. M.; JESUS, L. S.; BORGES, F. Q. A dinâmica sustentável após a operação arco de fogo no município verde (Paragominas – Pará). **Revista Observatório de la economia latinoamericana**. 2019. Disponível em: <https://www.eumed.net/rev/oel/2019/01/dinamica-sustentavel.html> . Acesso em: 26 set. 2023.

PIMENTEL, G. M. **Monitoramento das paisagens de Paragominas: uma abordagem geossistêmica.** 2016. 110 f. Dissertação (Mestrado em Gestão dos Recursos Naturais e Desenvolvimento local na Amazônia) – Universidade Federal do Pará, Belém, 2016.

RAMOS, W. F.; RUIVO, M. L. P.; SOUSA, L. M.; CASTRO, R. M. S. Crimes ambientais contra a flora e desmatamento no município de Paragominas, PA, de 2010 a 2017. **Brazilian Journal of Development**, v. 6, n.º 8, p. 66033-66048, 2020.

REDWAN, A. N. Z.; MAIA, L. F. T.; MARQUES, M.; DIAS, N. D. **Análise do setor moveleiro da microrregião de Paragominas e seus efeitos sobre o desenvolvimento.** 2007. Disponível em: https://www.inicepg.univap.br/cd/INIC_2007/trabalhos/sociais/epg/EPG00106_07C.pdf. Acesso em: 10 set. 2022.

REZENDE, L.; KAISER, I. M.; PEIXOTO, A. S. P. Vulnerabilidade ambiental das margens do rio Tiete. **Revista Gestão & Sustentabilidade Ambiental**, v. 7, n. 1, p. 136-166, 2018.

RIBEIRO, T. R. D.; MACIEL, M. N. M.; PANTOJA, M. A. L.; BRASIL, I. D. S.; FERNANDES, W. A. Análise de conflitos de uso da terra e passivos ambientais em áreas de preservação permanente na bacia do Uraim - Paragominas - PA. **In: SIMPÓSIO BRASILEIRO DE SENSORIAMENTO REMOTO. 18. 2017.** São Paulo. **Anais eletrônicos.** Disponível em: BIBLIOTECA ONLINE - ANAIS SBSR - SBSR 2023. Acesso em: 20 mar. 2023.

ROCHA, L. S.; MAIA, S. V. S. L. **Perfil de produção dos agricultores familiares da Colônia do Uraim, Paragominas - PA. 2018.** Trabalho de Conclusão de Curso (Graduação em Engenharia Florestal) - Universidade Federal Rural da Amazônia, Paragominas, 2018.

RODRIGUES, R. S. S.; SILVA, M. N. A.; FERREIRA FILHO, D. F.; SILBA, P. E. S.; FIGUEIREDO, N. M. Analysis of the effects of an extreme rainfall event on runoff in a small, rural Amazonian watershed. **Revista Brasileira de Climatologia**, v. 26, p. 68-392, 2020.

RODRIGUES, T. E.; SILVA, R. C.; SILVA, J. M. L.; OLIVEIRA JÚNIOR, R. C. N.; VALENTE, M. A. **Characterization and classification of soils in the municipality of Paragominas, Pará State.** BELÉM: EMBRAPA, 2003.

SANTOS, A. O.; SILVA, R. C. R. Agroforestry systems in the municipality of Paragominas, Pará. **Holos**, v. 3, e 9548, 2020.

SANTOS, C. A. ALVES, L. F. N.; FARIAS, M. H. C. S.; PINHEIRO, J. B. S. Preliminary study of the process of introduction of new productive activities: the case of black pepper in the Luiz Inácio settlement in Paragominas-PA. **Geoambiente online**, n.25, p.21-41, 2015.

SANTOS, C. E.; MANNCUSO, M. A.; TOEBE, M.; SCHULLER, T. S. Mapping the potential for groundwater and surface water contamination by pesticides in the northeast of Rio Grande do Sul. **Revista Geociências**, v. 40, n. 4, p. 951-966, 2021.

SANTOS, E. M.; PIKANÇO, O. A. S. **Restauração do ecossistema florestal da nascente do rio Uraim, localizada no município de Paragominas/PA**. 2008. Monografia (Especialização em Gestão da Água e do Meio Ambiente) - Universidade Federal do Pará, Belém, 2008.

SANTOS, N. G.; HERREROS, M. M. A.; BELTRÃO, N. E. S. O custo do desmatamento em um país verde: uma análise a partir de dados globais. **Colloquium, Organização e Desenvolvimento Sustentável**, v. 8. p. 197-2011, 2017.

SCHUBERT, H.; RAUCHECKER, M.; CLAVO, A. C.; SCHÜYY, B. Land use changes and their perception in the Hinterland of Barranquilla, Colombian Caribbean. *Sustainability*, n.º 11, 2019.

SIEDE, J.; HERMANN, AZ.; TISSOT-SQUALLI, M. L. Análise das principais formas de contaminação dos recursos hídricos superficiais e subterrâneos por resíduos de pesticidas. . 2018. Disponível em: <https://publicacoeseventos.unijui.edu.br>. Acesso em: 20 mar. 2023.

SILVA, A. E. P.; ANGELIS, C. F.; MACHADO, L. A. T.; WAICHAMAN, A. V. **Influência da precipitação na qualidade da água do rio Purus**. 2008. Disponível em: <https://acta.inpa.gov.br/fasciculos/38-4/BODY/v38n4a17.html>. Acesso em: 10 mar. 2023.

SILVA, L. M. S. **Avaliação da produção de mudas destinadas a arborização urbana no viveiro municipal de Paragominas/PA**. 2023. Monografia (Especialização em Arborização Urbana) – Universidade Federal Rural do Rio de Janeiro, Seropédica, 2023.

SOARES, D. A. S.; LEITE, A. S.; LOBATO, M. M.; CASTRO, C. J. N. Uso da terra em Paragominas (PA): espaço geográfico e classes sociais. **Revista Tocantinense de Geografia**, n.08, 2016.

SOUSA, L. M.; ADAMI, M.; LIMA, A. M. M.; RAMOS, Avaliação do uso e cobertura da terra em Paragominas e Ulianópolis, utilizando dados do Projeto TerraClass. **Revista Brasileira de Cartografia**, n.º 69, p. 421-431, 2017.

SOUSA, S. C.; SILVA, F. L. Mapas de uso e cobertura da terra para apoiar políticas públicas no Assentamento Rural Paragonorte. **Holos**, v. 8, e 10146, 2020.

SOUSA, S. L. S. **Geotecnologias aplicadas à análise socioambiental do alto curso da bacia hidrográfica do rio Uraim (Paragominas-PA): contribuições aos estudos integrados**. 2019. Trabalho de Conclusão de Curso (Tecnólogo em Geoprocessamento) – Universidade Federal do Pará, Ananindeua, 2019.

SOUZA JÚNIOR, C. A.; SHIMBO, J. Z.; ROSA, M. R.; PARENTE, L. L.; ALENCAR, A. A.; RUDORFF, B. E. T.; HASENACK, H.; MATSUMOTO, M.; FERREIRA, L. G.; SOUZA-

FILHO, P. W. M.; OLIVEIRA, S. W.; ROCHA, W. F.; FONSECA, A. V.; MARQUES, C. B.; DINIZ, C. G.; COSTA, D.; MONTEIRO, D.; ROSA, E. R.; VÉLZ-MARTIN, E.; WEBER, E. J.; LENTI, F. E. B.; PATERNOST, F. F.; PAREYN, F. G. C.; SIQUEIRA, J. V.; VIEIRA, J. L.; FERREIRA NETO, L. C.; SARAIVA, M. M.; SALES, M. H.; SOUZA, R. C. **Estratégias dos agricultores familiares para lidar com a situação de seca na colônia Uraim em Paragominas - PA. 2018.** Monografia (bacharelado em Engenharia Florestal) - Universidade Federal Rural da Amazônia, Paragominas, 2018.

TRITSCH, I.; SIST, P.; NARVARES, I. S.; MAZZEI, L.; BLANC, L.; BOURGOIN, C.; CORNU, G.; GOND, V. Multiple patterns of forest disturbance and logging shape forest landscapes in Paragominas, Brazil. **Forest**, v. 7, n. 315, 2016.

VALE, J. R. B.; CRUZ, H. S.; BARBOSA, M. T.; LOPES, R. D.; CAMPOS, S. C. C. Crescimento urbano e impactos sobre a cobertura vegetal na área de influência da Avenida João Paulo II, região metropolitana de Belém-Pará. **Revista Tocantinense de Geografia**, v. 10, n.º 22, p. 164-180, 2021.

VENCESLAN, B. B.; SILVA, D, C. C. A constituição de um ambiente de negócios em áreas de desmatamento. *Oidles Desarrollo local y Economía social*, v. 15, n.º 30, 2021.

VIEIRA, D. M. S.; TORRES, J. L. R.; OLIVEIRA, L. M.; GONÇALVES, O. R.; OLIVEIRA, M. A. Morfometria e qualidade da água da microbacia do Córrego do Sapecado, afluente do rio Uberaba. **Global Science and Technology**, v. 05, n.º 03, p. 11-22, 2012.

YOUNG, C. E. F.; BAKKER, L. B. Lista positiva com mecanismos de incentivo aos produtores rurais do município de Paragominas (Pará). 2015. Disponível em: <https://ipam.org.br/wp-content/uploads/2017/02/Relatorio-final-Registro-Verde-Paragominas.pdf>. Acesso em: 30 mar. 2023.

WATRIN, O. S. Análise espaço-temporal do uso da terra em microbacias hidrográficas no município de Paragominas, estado do Pará. In: SIMPÓSIO BRASILEIRO DE SENSORIAMENTO REMOTO. 13. Santa Catarina. 2007. **Anais eletrônicos**. Disponível em: 7019-7026.pdf (embrapa.br). Acesso em: 30 mar. 2023.

Cenário II. Análise das condições ambientais hídricas do trecho urbano do igarapé Paragominas.

ARTIGO 2

Environmental integrity in two areas of the Paragominas stream in the municipality of the same name, Pará, Brazil

RESUMO

A urbanização tem como um dos pontos negativos, os impactos antrópicos e as condições ambientais que alteram, nos corpos hídricos urbanos, o Índice de Integridade do Habitat- IIH. Tais fatos podem ser investigados e analisados com a aplicação do IIH. O objetivo desta pesquisa foi gerar dados sobre o igarapé Paragominas a partir da Rodovia C. do Sacramento e Residencial Selecta para mostrar o real estado destas duas variáveis ambientais, até então inexistentes. O método aplicado foi o exploratório, observacional e de natureza qualitativa e quantitativa. Os resultados obtidos indicaram que na Área 1, a rodovia Constantino Pereira do Sacramento, os impactos antrópicos ($\Sigma_{total} = 55$) e as condições ambientais ($\Sigma_{total} = 46$) provocaram alterações médias na Integridade do habitat ($\Sigma_{total} = 47,2\%$). Na Área 2, residencial Selecta, a 518 m da PA 125, os impactos antrópicos ($\Sigma_{total} = 31$) provocaram modificações nas condições ambientais ($\Sigma_{total} = 29$), especialmente no uso e ocupação solo com supressão vegetal, o que alterou de forma significativa a integridade do Habitat ($\Sigma_{total} = 28,6\%$). Por isto, pode-se concluir que a urbanização e a construção de espaços residenciais marginais em corpos hídricos causam alterações no habitat de animais e vegetais, embora ainda mantenha um dos quatro serviços ambientais: a balneabilidade.

Palavras-chave: Corpos Hídricos Urbanos. Serviços Ecossistêmicos. Qualidade da Água. Área de Proteção Permanente.

ABSTRACT

One of the negative aspects of urbanization is the anthropogenic impacts and environmental conditions that alter the Habitat Integrity Index (HII) in urban water bodies. These facts can be studied and analyzed using HII. The objective of this research was to generate data on the Paragominas stream from the C. do Sacramento highway and Residencial Selecta, in order to show the real state of these two environmental variables, in these two locations, which had not been available until now. The methodology applied was exploratory, observational, qualitative, and quantitative. The results obtained showed that in Area 1, the Constantino Pereira do Sacramento Highway, anthropogenic impacts ($\Sigma_{total} = 55$) and environmental conditions ($\Sigma_{total} = 46$) caused an average change in habitat integrity ($\Sigma_{total} = 47.2\%$). In Area 2, Residencial Selecta, 518 m from PA 125, anthropogenic impacts ($\Sigma_{total} = 31$) caused changes in environmental condition ($\Sigma_{total} = 29$), especially in land use and occupation with vegetation suppression, which significantly altered habitat integrity ($\Sigma_{total} = 28.6\%$). Therefore, it can be concluded that urbanization and the construction of marginal residential areas on water bodies cause changes in the habitat of animals and plants, although it still maintains one of the four environmental services: bathing.

Keywords: Urban Water Bodies. Ecosystem Services. Water Quality. Permanent Protection Area.

RESUMEN

Las aguas superficiales de las zonas urbanas se ven directamente afectadas por la expansión urbana, especialmente por la pérdida de vegetación ribereña y las alteraciones de la estructura física de los meandros. Teniendo esto en cuenta, hay una falta de información sobre los impactos antropogénicos y las condiciones ambientales del Paragominas *Creek*, en el municipio de Paragominas, en el estado de Pará. Por lo tanto, el objetivo de esta investigación fue generar datos sobre tres variables: urbanización, impactos antropogénicos y condiciones ambientales en tres áreas urbanas y las consecuencias para las Paragominas *Creek*. El método utilizado fue la investigación exploratoria con cobertura cualitativa y cuantitativa, para medir el Índice de Integridad del Hábitat (IIH). Los datos obtenidos y analizados indicaron que las tres áreas presentan valores tanto de impactos antropogénicos (A1 = 4,4; A2 = 3,8; A3 = 5,3) como de condiciones ambientales (A1 = 3,4; A2 = 0,4; A3 = 5,1), que afectan la calificación del IIH. En consecuencia, el índice de integridad medioambiental (A1 = 7,8; A2 = 4,2; A3 = 10,4) se clasificó como "muy afectado" en las tres zonas. Por lo tanto, los gestores municipales deben elaborar urgentemente planes de acciones de control, mitigación y reparación en el área urbana del arroyo Paragominas.

Palabras clave: Urbanización. Impactos Antropogénicos. Condiciones Medioambientales. *Green Lake*.

1 INTRODUCTION

Among the most frequent problems affecting urban streams, one of them, the suppression of the riparian forest, results in alterations to the Habitat Integrity Index - IIH (Santos et al., 2021). It is a quick way to establish the state of environmental conditions, whose analyzed variables, whose quantities can be adapted to various types of research and allow them to be associated with the processes of hydro-environmental degradation (Santos; Oliveira; Mortati, 2017). In the context of environmental degradation, when plant suppression occurs, the most effective consequence is the loss of habitat for countless species, whether plants or animals, because their reproduction and feeding are linked to this type of vegetation (Attanasio et al., 2012). Another problem resulting from the loss of this forest is the loss or modification of permanent protected areas, with in the national territory have their guidelines in Law No. 12.651, then called the "New Brazilian Forest Code" (Brasil, 2012).

The water body that is the subject of this research, then called Paragominas stream, is a right margin tributary of the Uraim River micro-basin and is affected by anthropogenic impacts such as urbanization (Garcez, 1988; Tundisi et al., 2008) and land occupation (farms, sawmills, ranches, farms, among others), the construction of residential complexes such as Residencial Selecta, whose access road is located on the banks of this stream.

The erosion and the growth of surface runoff is another problem that results from the loss of vegetation cover. Silva et al. (2018) discussed this fact in detail, stating that urbanization produces this consequence. It also causes an increase in surface runoff, as well as a reduction in the process of infiltration. The problem expands into negative consequences because there are government regulations that regulate it:

Normative Instruction No. 06 (SEMAS, 2011), which in Article 2 deals with the granting of a license for the suppression of plants, but there is no compliance with this.

However, it should be noted that at the beginning of the territorial expansion of this municipality (1965), this legislation did not yet exist. All these arguments and the lack of specific literature on the Paragominas stream justify this research and increase its relevance. The aim is therefore to find answers to two questions: 1) Have anthropogenic impacts affected the environmental conditions of this water body? 2) Has this altered its Habitat Integrity? This will generate data on anthropogenic impacts and environmental conditions in two urban areas of the Paragominas Igarapé.

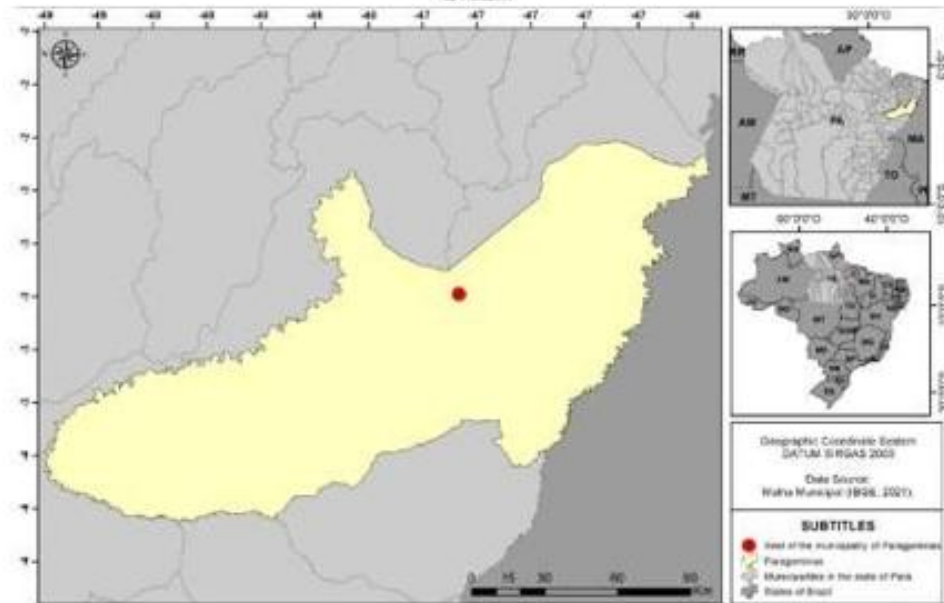
This research is organized into six sections: 1) Introduction, where the authors set out the problem and elaborate the theoretical framework; 2) Material and Methods, which contains a description of the steps taken to structure the data search; 3) Presentation of the results obtained for anthropogenic impacts, environmental conditions and the Environmental Integrity Index (IIH); 4) Discussion with the authors about the results obtained; 5) The Conclusion, where the authors express their opinions about the answers to the two guiding questions of the re- search and, the References, where the authors who allowed the elaboration and discussion of the corpus of this research were cited.

2 MATERIAL AND METHODS

2.1 PHYSIOGRAPHY OF THE MUNICIPALITY

The municipality of Paragominas (Figure 1), in the southeast of Pará, is located 316 km from the capital of the state of Pará, Belém, between the parallels of 2°38' and 3°40' - S, and 46°27' and 48°50' E Greenwich (Rodrigues *et al.*, 2003) Access is via two highways (BR - 010; PA 125). The vegetation is made up of a mixture of Ombrophilous Forest and Dense Alluvial Ombrophilous Forest (Watrín; Rocha, 1992), all in soil classified as Yellow Latosol, where nutrients were stored from forest fires during the process of colonization of this area.

Figure 1. Location map of the municipality of Paragominas, southeast of the state of Pará, Brazil.



Source: Prepared by Santos, Y. P.

The climate classification, according to Köppen, is Aw: tropical rainy, with a well-defined dry period between June and November. Annual rainfall averages 1,743 mm between December and May. The Paragominas stream serves the rural community and therefore has a large number of dams (± 11) which serve as reservoirs for livestock watering/agricultural irrigation. It also serves as a right-bank tributary of the Uraim River, which also runs through the urban area, since the slope of this stream crosses the urban area of this municipality (Rodrigues *et al.*, 2020).

2.2 METHOD

The method used was exploration, observational in nature and qualitative-quantitative in scope, as described by Callisto *et al.* (2002). In order to use it effectively, the Rapid Habitat Assessment Protocol was used because it allows an effective analysis of anthropogenic impacts on stretches of the watershed, using the Habitat Integrity Index (HII) which, according to Mitchell (1996), allows the most accurate information to be obtained about a given reality.

To complete the HII, the study of anthropogenic impacts on the water body, with the aim of generating data for municipal management and contributing to effective environmental monitoring, was associated with an assessment of the habitat, since, according to Almeida *et al.* (2021), anthropogenic alteration is the greatest cause/threat of species extinction. For this reason, this association became the justification for using it in this research, as it will allow and contribute to future studies on this stream, regarding the maintenance and environmental conservation of this stream, and associate it with the evolution or involution of the habitat.

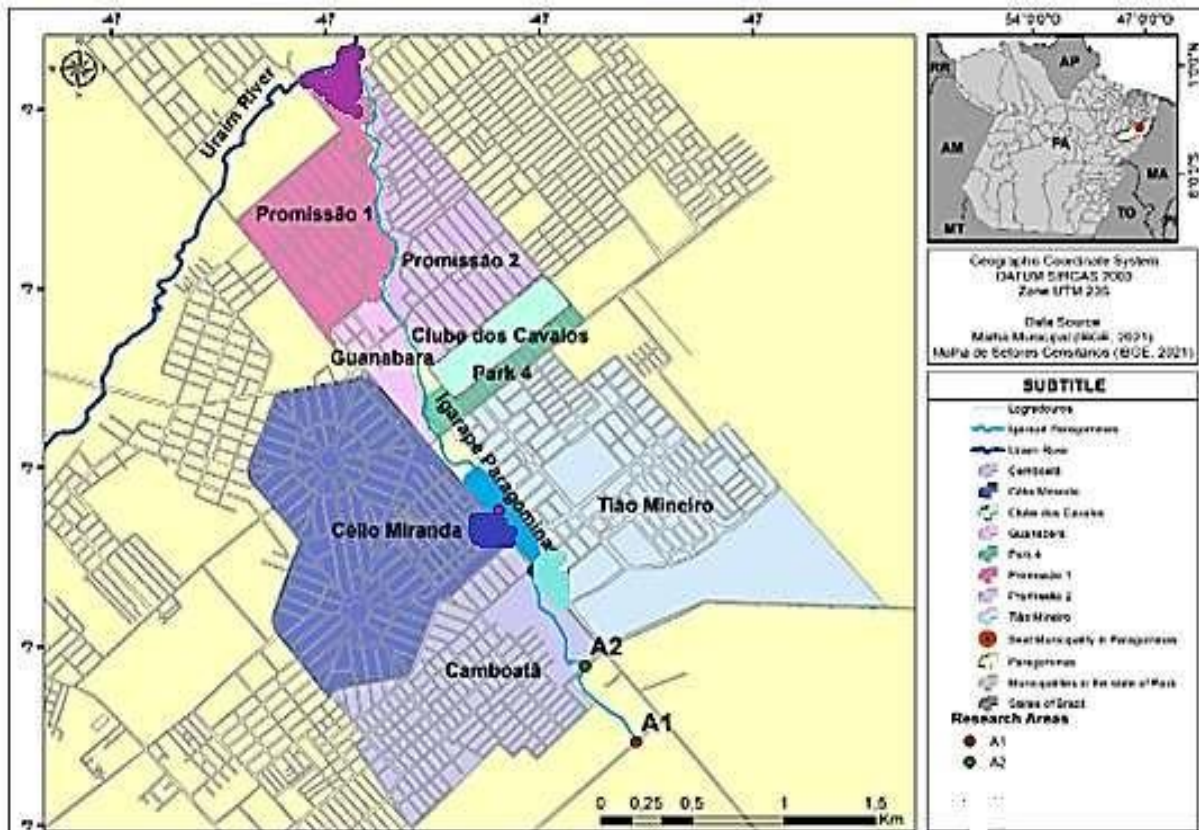
With these two pieces of information, the development of measures to monitor and control the quality of the environment by the bodies that manage water resources

in the municipality of Paragominas becomes more effective, as does the application of mechanisms for environmental quality and, consequently, habitat quality in this stream.

2.2 SELECTED AREAS

Two areas were selected: A₁) the sparsely urbanized stretch, localized at 850 m of PA 125 Highway, West-East, called Constantino Pereira da Sacramento Highway. A₂), urbanized area, called Residencial Selecta, west-East, left board, In this area, the Hydrical body, is localized at 518 m of PA 125 highway, the access point to the aforementioned complex (Figure 2).

Figure 2. Location of the two areas covered by this research that flow directly/indirectly into Paragominas stream municipality of same name. Pará, Brazil.



Source: Prepared by Santos, Y. P. 2024

The choice of these two areas is justified: Area 1, based on the information about the development of the municipality of Paragominas contained in the book "Paragominas, the reality of knowledge" (Leal, 2000), which relates facts that indicate that the old Pioneers' Highway, today called Constantino Pereira do Sacramento, was the reception point for people coming in search of land. Area 2, on the other hand, marks the end of the timber trade and the need for new architectural units to serve the new communities, with the installation of the Residencial Selecta, which was assigned to Bairro Camboatã in the recent administrative reform.

2.3 OBTAINING DATA

2.4.1 Primary

The Board one was used to obtain this data. In the first, seven parameters related to anthropic impacts (right) were allocated, based on what was proposed by the Ohio Environmental Protection Agency (EPA, 1987). For the environmental conditions of the water body, a qualitative and quantitative adaptation was made based on that proposed by Hannaford, Barbour and Resh (1997).). For the environmental conditions of the water body, a qualitative and quantitative adaptation was made based on that proposed by Hannaford, Barbour and Resh (1997).

Board 1. Qualitative and quantitative identification of the anthropic impacts and environmental conditions of the Paragominas stream. Municipality of the same name, Pará, Brazil.

Anthropic Impacts			Environmental Conditions		
	Qualitative	Quantitative	Qualitative	Quantitative	
Original features almost all intact	Great	4	Alterations	<i>In natura</i>	5
	Good	3		Light	4;3
Few changes	Regular	2		Moderate	2;1
Impacts that interfere with the morphophysiology of the ecosystem	Terrible	1		Severe	0

Source: Prepared by the authors themselves.

In order to better express the reality of anthropic impacts, an association was made between the types of anthropic impacts identified for each of the seven parameters of the Paragominas Stream that were altered by their occurrence (Board 2). Quantitative similarity in the number of parameters was maintained, i.e., seven of the 21 identified by Hannaford, Barbour and Resh (1997). Those selected are inherent to better identifying and characterizing the environmental conditions of the Paragominas stream.

Board 2. Seven evaluation parameters for anthropic impacts. Paragominas Stream. Municipality of the same name, Pará, Brazil.

Location:		
Collection site:		
Weather on the day of collection:		
Collection method :		
Type of environment:		
Average Width (m):		
Average Depth (m):		
Average Water Temperature (°C):		
Nº	Anthropic Impacts	Environmental conditions
1	Presence/absence of foreign material	Presence/absence of foreign material
2	Physical changes in the water body meander	Substrate type
3	Margin stability	Changes to the water body channel
4	Type of land use and occupation	Water flow
5	Conservation status of the surrounding vegetation	Maintenance of the riparian forest
6	Erosion near and/or the edge of the hydric body	Extent of riparian forest
7	Anthropic alterations	Presence of the water plants

Source: Adapted from Callisto *et al*, 2002

In these two boards, the data is allocated in directions that allow for greater understanding in the discussion of what was perceived and identified in the areas analyzed (Board 3).

Board 3. Entering data into the spreadsheets used for Anthropic Impacts and Environmental Conditions of the Paragominas Stream. Municipality of Paragominas, Pará, Brazil.

LOCAL	DIRECTION	REFERENCE
Highways	West (W) → East (E)	- PA 125. - Constantino Pereira do Sacramento.
Urban subsystem	North (N) → South (S) and/or West (W) → East (E)	- Selecta Avenue.
Hydrcal body	Upstream (U) to downstream (D)	Highway, avenues and streets.

Source: Prepared by the authors themselves

2.4.2 Secondary

In order to obtain this data, a variety of literature was selected, but all of it related to the subject of this research (Board 4).

Board 4. Acquisition of secondary data to compose the corpus of this research.

Types	Specifications	Names
Monography	Dissertations and Theses	Pará State University (UEPA); Pará Federal University (UFPA); Pará Federal Rural University (UFRA), among others.
Articles	Scientif publications	<i>Digital Science</i> , Geografares, Revista Brasileira de Geografia Física, Revista Brasileira de Recursos Hídricos, PLOS Water, Portal de Periódicos da Coordenação de Pessoal do Ensino Superior, <i>Scientific Eletronic Library Online</i> , <i>Studies Publicações</i> , <i>World Scientific</i> , among others.
Hemerographies	Technical documents, books and e-books, technical notes, specialized links, science journalism, among others.	Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA). Instituto Nacional de Pesquisas na Amazônia (INPA). Agência Nacional de Águas E Saneamento (ANA).

Source: Prepared by the authors themselves.

A period was not established because pioneering literature (Allan, 1995; Mitchell, 1996; Prabhu; Colfer; Dudley, 1996) was used to provide a better basis for the evolution of the subject of this research with later data and to generate more consistent data. However, priori was given to literature published in the last five years (2019 and 2023) to give consistency to previous studies and to verify the application of the Habitat Integrity Index to anthropogenic impacts and environmental conditions in urban stream reaches.

2.5 CALCULATION MADE

The calculations made for both anthropogenic impacts (Equation 1) and environmental conditions (Equation 2) enabled the composition of the Habitat Integrity Index - IIH (Equation 3) for the Paragominas stream

Integrity Index - IIH (Equation 3) for the Paragominas stream.

$$\text{Anthropic Impacts}(\%) = \frac{(\text{Sum of the value set for each parameter}) \cdot 100}{\text{Total sum fo all valued parameters}} \quad (1)$$

$$\text{Environmental Conditions} (\%) = \frac{(\text{Sum of the value set for each parameter}) \cdot 100}{\text{Total sum fo all valued parameters}} \quad (2)$$

$$HII = \bar{x}_{AI} + \bar{x}_{E.C} \quad (3)$$

Onde:

HII = Habitat Integrity Index (%)

\bar{x}_{AI} = Average value of anthropogenic impacts identified and valued.

\bar{x}_{EA} = Average value of the environmental conditions of the areas analyzed, in the urban stretch of the Paragominas stream.

The scale of Nessimian *et al.* (2008) was adapted to analyze the qualitative and quantitative proportional contributions of anthropogenic impacts and environmental conditions on the HII. To establish the Integrity Index, the scale recommended by Callisto *et al.* (2002) was applied. According to this author, only the environment whose values were between $78\% \leq HII \leq 100\%$ would be considered "natural" (Table 1).

Table 1. Proportional qualitative and quantitative contributions of anthropic impacts and environmental conditions to the Habitat Integrity Index - IIH. Paragominas stream. Municipality of the same name, Pará, Brazil.

Analyzed variables	Contribuciones		HII	
	Qualitative	Quantitative (%)	Qualitative	Quantitative
Anthropic Impacts more	High.	$0 \geq CP \leq 40$	Highly impacted	$0 \leq \sum \leq 30$
	Medium.	$41 \geq CP \leq 70$	Impacted	$31 \geq \sum \leq 51$
Environmental conditions	Low.	$71 \geq CP \leq 100$	Altered	$52 \leq \sum \leq 77$
			Natural	$78 \geq \sum \leq 100$

Adapted from Nessimian *et al.* (2008).

3 RESULTS

3.1 AREA 1 (A1)

The area in question is located on a stretch of PA 1256, 850 m, in an E → W direction. This highway was formerly called "of the Pioneers" and is now called Constantino Pereira do Sacramento Highway(Figure 3).

Figure 3. Section of the Constantino Pereira do Sacramento highway where the study area is located. Municipality of Paragominas, Pará, Brazil.



Source: Santos, Y. P. (2024).

3.1.1 Anthropogenic impacts

The data obtained and analyzed indicate that the Paragominas stream makes a high contribution (28%), especially with regard to the expansion and deformity of the natural meander at this location (Table 2).

Table 2. Qualitative and quantitative identification of anthropogenic impacts on the Paragominas stream. Municipality of the same name, Pará, Brazil.

Location: Rodovia Constantino Pereira do Sacramento Highway, 850 m from PA 125, east west direction. Date of collection: 05/06/2024 Weather on the day of collection: clear, sunny day with 26° C. Method of collection: Observational, with the production of a photographic memorial. Type of environment: Transition between rural and urban areas. Average Width (m): 149 Average depth (m): 110.6 Average Water temperature (°C): 29.7			
Parameter 1: Presence/absence of allochthonous material.			
Modifications to the natural structure of the stream body with allochthonous material.	Minor modifications, with the addition of other materials to the banks, such as gravel to level the ground	Moderate disposal of allochthonous material on the banks, but with little dragging into the water body, due to the maintenance of the secondary riparian forest.	Allochthonous material deposited on the banks of the water body is dragged into the body, causing deposition on the substrate, modifying habitat, altering turbidity, causing siltation, among other functional aspects
(1)	(2).	(1).	(1). $\Sigma = 5$
Parameter 2: Physical changes in the meander of the watercourse			
At the research site, there are no meanders. An irregular area similar to a circle.	At the research site, there are no meanders. An irregular area similar to a circle.	At the research site, there are no meanders. An irregular area similar to a circle.	At the research site, there are no meanders. An irregular area similar to a circle.

(1)	(2)	(1)	(1)	$\Sigma = 5$
Parameter 3 : Bank stability.				
On the highway: secondary vegetation with shrubs and herbaceous plants.	On the highway: secondary vegetation with shrubs and herbaceous plants.	On the highway: secondary vegetation with shrubs and herbaceous plants.	On the highway: secondary vegetation with shrubs and herbaceous plants.	
(1)	(2)	(4)	(4)	$\Sigma = 11$
Parameter 4: Type of land use.				
Construction of road paving with establishment of canalization 850 m from PA 125 highway.	In Fazendinha, occupation by sawmills, now deactivated, deactivated pastures.	In Fazendinha, the current occupation is scarce and sparse. However, there are still garages that are used for washing dishes and clothes.	The left margin, in the upstream-down-stream direction, still offers an area of damaged drainage, the waters of which are used for recreation: bathing, picnicking, pole and/or fishing.	
(1)	(2)	(3)	(3)	$\Sigma = 9$
Parameter 5: Conservation status of the surrounding vegetation				
In the U → D_ left margin direction: altered, based on the heterogeneous height of the canopies.	In the frontal context, direction W → E, i.e., where there is road surfacing, absent.	In the U → D, direction, the presence of secondary vegetation, even in fragments, mitigates the impacts caused by the sawmills that once existed there.	On the right margin of the road, in the W → E direction, where the drain is located, the vegetation is tree-like. This improves the conservation conditions but is secondary.	
(1)	(1)	(2)	(2)	$\Sigma = 6$
Parameter 6: erosion near and/or on the bank of the water body				
In the U → D_ left margin direction, no erosion was observed.	In the frontal context, in the W → E direction of the road paving, erosion is present in the bridge cutting groove	In the U → D_ right margin direction: marginal erosion occurs when there is flooding that causes soil particles to shift	On the right margin of the road, in the W → E direction, erosion is also dependent on flooding or the rainy season.	
(4)	(2)	(2)	(2)	$\Sigma = 10$
Parameter 7: Anthropogenic changes				
Towards U → D_ left margin presence of slopes; settlement of recreational parks for the community.	In the frontal context, direction W → E of the road paving: part of the canal has been landfilled and offered in plots for sale and future construction.	In the direction of U → D_ right margin: anthropogenic alterations are observed, as there are "backyards" on the bank for private recreation.	Also, in this direction and margin: the construction of culverts so that the wastewater flows into the Paragominas stream.	
(1)	(1)	(1)	(1)	
$\Sigma_{total} = 31.$				

Source: Prepared by authors themselves.

3.2.2 Environmental condition

When analyzing the seven parameters in terms of A₂'s environmental condition, two of them (parameters two and four) obtained cumulative values equal to two, in addition to parameter 5, whose cumulative value was equivalent to 1. These values helped indicate that the environmental condition is out of balance (Table 3).

Table 3. Qualitative and quantitative identification of the environmental condition of stream Paragominas. Municipality of the same name, Pará, Brazil.

Parameter 1: Riparian vegetation at a distance of 10 m from the water surface				
In the Highway: herbaceous and shrubby, secondary. A 30 m stretch without vegetation cover, before and after the fountain.	In Fazendinha, trees and shrubs, secondary along the entire length of the waterfront, in an east-west direction.	In the east-east direction, on the right margin, there is herbaceous vegetation ($0.5 \text{ m} \leq h \leq 1.5 \text{ m}$), shrubs ($1.5 \text{ m} \leq h \leq 3.0 \text{ m}$) and trees ($h \geq 3.0 \text{ m}$), all secondary.	On the left margin of the highway, eastbound, from PA 125, before and after the drain, there is no vegetation cover.	$\Sigma = 6$
(1)	(2)	(2)	(1)	
Parameter 2: Changes in the water body channel				
Right margin: Asymmetrical islands causing anastomosis in the canal.	Central channel: presence of submerged and immersed logs, attached to the rocky bottom. Remains of concrete Wall anastomosing the channel.	Left margin: The asymmetrical islets are located just beyond the bank, entering the water's edge.	Presence of galvanized pipes (source → drain, 15.1 m apart, 36 cm level) in a concrete structure in the central gutter.	$\Sigma = 4$
(1)	(1)	(1)	(1)	
Parameter 3: Water flow				
At Fazendinha, due to the massive presence of aquatic vegetation ($\bar{x} = 3\text{m}$), backwater areas were created.	In the central channel, there are submerged and immersed trunks, which modify the habitat of nektonic species and reduce both the flow of nutrients and water.	The presence of asymmetrical islands in the interior, which interfere with the flow of water in the natural habitat, in the U → D direction, on both the left and right margins, and a low concentration of them in the central channel.	At the source-drain, the slope is tiny (- 36 cm). During the rainy season, this may have caused a narrowing of the water flow, which raised the water level in this area, causing flooding and dragging the "islet of vegetation" onto the road pavement.	$\Sigma = 4$
(1)	(1)	(1)	(1)	
Parameter 4: Maintenance of riparian forest				
On the highway: direction U → D, from the PA 125, both on the right and left margins, the riparian forest has been suppressed. However, the resilience of the soil has led to natural regeneration on the site.	In the central channel, in the same direction, and from the same location, at 850 m, the riparian forest was completely suppressed to make up the canal pipe.	In the Fazendinha area, the riparian forest also has a secondary regenerative character, although it is better preserved when compared to the highway.	In general, there was no conservation of the riparian forest in this area, but natural regeneration occurred in almost all of the stream area under analysis.	$\Sigma = 8$
(2)	(1)	(3)	(2)	

Parâmetro 5: Extensão da mata ciliar				
C. P. do Sacramento Highway: Where the concrete structure was built to support the culvert on both the right and left margins, there is no trace of riparian forest. (1)	From the edge of the highway, the secondary riparian forest extends 7m down to the water's edge, although there is a predominance of herbaceous plants. (2)	When it reaches the manhole structure, this distance decreases to 3 m. (1)	On the left margin, in the direction of U → D, the distance from the road to the water level is reduced to 5 m. (1)	$\Sigma = 5$
Parameter 6: Presence of aquatic plants				
On the C. P. do Sacramento Highway, direction W → E there is a predominance of macrophytes (<i>Eichhornia</i> spp) and reeds. (3)	At Fazendinha, the stream bed has shrubby aquatic plants. (3)	On the left margin, there is an islet in the upstream-downstream direction, and the aquatic plants are herbaceous. (3)	In the central gutter, aquatic vegetation becomes scarcer, only 3m from the culvert, and this creates a fast-flowing area for the water. (2)	$\Sigma = 11$
Parameter 7: Type of background				
On the left margin, the bottom is sandy-clayey. (2)	On the bank of Fazendinha, there is a muddy bottom. (1)	The central trough has a stony bottom. (2)	On the right margin, the bottom is muddy due to the presence of leaf litter and vegetation. This is the sub-area with the least human activity. (3)	$\Sigma = 8$
$\Sigma_{Total} = 46$				

Source: Prepared by the authors themselves.

3.2.3 Habitat Integrity Index (HII)

The classification of this area, as proposed by Callisto et al. (2002), is "highly impacted". This classification is based on the values for the qualitative average between anthropogenic impacts and environmental conditions for A_2 , which were similar ($\bar{x} = 14.3\%$). With this, the value for IIA₂ is equivalent to 28.6%.

4 DISCUSSIONS

4.1 ANTHROPIC IMPACTS

The cumulative values obtained for A_1 (55), compared to A_2 (46), for anthropogenic impacts, show that when extensive watersheds or micro-basins are subjected to research into natural conditions, it is possible to assess the state of their natural condition. This aspect was assessed and measured by Callisto et al. (2002) in streams in the Serra do Cipó National Park, Minas Gerais, where the author identified both altered and impacted areas.

In the municipality of Paragominas, in A_1 , the anthropogenic impacts have not been as severe, as the area still has the conditions to function as a "bathing area (Figure 5a)" as well as a fishing area (Figure 5b).

Figure 5. Ecosystem services provided in A1 for (a) bathing and (b) provisioning (fishing). Paragominas stream. Municipality of the same name, Pará, Brazil



Source: Prepared by authors themselves.

These facts may be related to the state of conservation of the habitat, as the surrounding vegetation becomes a conservation mechanism for the aquatic habitat, as it filters, retains, and nourishes the aquatic fauna. In this perspective, Silva, P., and Silva M. (2020), researched the conservation of riparian vegetation in Uruará, Pará, and concluded that there was an emphasis on what they called igarapé 1, since they identified the presence of vegetation in two points of that water body, especially in terms of water quality. This corroborates the maintenance of the fauna and flora found in A1, in Paragominas, Pará.

At A₂, bathing is also effective, but it is restricted to the area where the water flows, where the abundance of aquatic plants is intense, including algae. Fishing is not effective, nor is the presence of vertebrates. The riparian forest was completely replaced by slopes during urbanization on the left bank, upstream → downstream, covered with grass, so land use and occupation interfere with the habitat's equilibrium conditions (Figure 6).

Figure 6. Balneability at A₂. Paragominas Igarapé. Municipality of Homonymous, Pará, Brazil.



Source: Prepared by authors themselves

Regarding the integrity of the habitat altered by urbanization, Araújo et al. (2020) conducted research in Rio Branco, Acre, and concluded that the more urbanization advances over ecosystems, the greater the changes, altering habitats, sustainability and communities, especially aquatic ones. The National Institute for Amazonian Research (INPA, 2024) states that the research conducted on forest alterations caused

in water bodies compromises the evolution of species because it alters the habitat. This may explain the absence of fish and other vertebrates observed in A₁.

4.2 ENVIRONMENTAL CONDITIONS

Analyzed from the values obtained for A₁ (46) and A₂ (29), it can be seen that environmental conditions are more degraded in A₂, which could lead to irreparable losses in biodiversity, as well as compromising water quality. In the context of habitat, Lemes *et al.* (2011) state that the survival of both animal and plant species depends on vegetation cover, the extent of the bodies of water they choose as "preferred" and, with this, increase biodiversity, allowing for better social well-being for the surrounding community.

In a study carried out in Tabatinga, a municipality in the state of Amazonas, Bezerra and Souza (2021) carried out research into the environmental degradation generated by urban occupation and concluded that this occupation is intrinsically associated with habitat loss, and the primary factor for this is the discharge of domestic effluents into the water body. In A₂, there are two effluent outlets that flow into the analyzed area. As a result, environmental conditions become extremely altered, which compromises the HII.

4. 2. 1. Habitat Integrity Index – HII.

The Habitat Integrity Index was lower in A₂ = 28.6% (Figure 7.A₂) than in A₁ = 47.2% (Figure 7.A₁). If you look at the presence/absence of vegetation cover, you can see that it is absent on the left bank of the A₁, and this is the biggest contributing factor to the decrease in the HII value. Also in this figure, it can be seen that this cover is 21.5 m from the water's edge, which has led to changes in the integrity of the habitat. Under the tops of these trees, the "recreation square" was set up, where the community exercises its right to recreation.

Figure 7. A₁, banks of the water body in this area and vegetation cover; A₂, left bank of the A₂ with a shortage of riparian forest. Igarapé Paragominas. Municipality of the same name, Pará, Brazil.



Source: Prepared by authors themselves.

In Figure 7.A1, vegetation cover, which is important for habitat maintenance, is still prevalent. This prevalence was researched in the municipality of Santarém, Pará, by Santos *et al.* (2021). The research covered six streams, from the project entitled Igarapés Urbanos (Urban Streams), and they concluded that the values obtained for identifying the HII, among the six streams analyzed, only one of them, called Irurama, preserved the integrity of the habitat (94%), that is, within the range established by Callisto *et al.* (2002). Therefore, in Paragominas, A2, there really is a loss of habitat integrity.

5 CONCLUSIONS

The values obtained for anthropogenic impacts identify a serious intervention in the environmental conditions of the Paragominas creek in the two areas analyzed. So much so that there was a significant alteration to environmental integrity in both, but in A2, when compared to A1, the alterations were more pronounced, which may be leading to the loss of endemic or non- endemic species, and this is valid for explaining the alterations in the physical- chemical parameters of the water in this body of water.

The application of a rapid protocol such as the Habitat Integrity Index was relevant for identifying and generating data on two areas in the urban stretch of the Paragominas Igarapé that, in A1, present a medium level of aggression in terms of anthropogenic impacts, which can be explained by the deactivation of commercial activities near this area. In addition, urbanization is still absent, although there is already asphalt sealing on Constantino Sacramento highway.

With regard to environmental conditions, with emphasis on vegetation cover, it was observed that marginal vegetation is still more prevalent than in A2. However, in A1, marginal erodibility is accentuated on both banks of the igarapé, as well as the dragging of sediments from the cutting of the culvert, which causes changes in the sediments and allocates substances foreign to the chemical composition of the water, which modifies the habitat.

Considering the values identified for A2, it can be said that the situation of anthropic impacts and environmental conditions have altered the integrity of the habitat, which is why no vertebrates (fish and chelonians) were observed, as occurred in A1. However, there was similarity in terms of the provision of one of the ecosystem services: recreation, i.e., bathing, but the alteration of the habitat and the loss of vegetation cover contribute to temperature mitigation.

In addition, if the slopes are consolidated, they could receive tree vegetation, which would positively modify the habitat for biodiversity. It is hoped that public administration bodies will be able to take advantage of the information contained here, since this is a pioneering study in this area, and draw up a recovery plan based on the installation of two ecologically correct bathing establishments, with workshops on environmental conservation of water bodies for future visitors.

ACNOWLEDEMENTS

We thank the State University of Pará for the doctoral scholarship awarded to the first author. The data related to urbanization in streams are being analyzed in the municipality of Paragominas, on a stream of the same name, scenario III of the first

author's doctoral thesis, developed in the Postgraduate Programme in Environmental Sciences (PPGCA) at this higher education institution. Mr. Ruy Marcos Minto for many transfers of the aluminum boat, and Mr. Ráulison Dias Pereira (Surveying Technician). Also, The Paragominas Municipal Department of the Environment (SEMMA) granted permission for this research, as well as the generation of useful data for the conservation of water resources.

REFERENCES

ALLAN, J. D. **Stream ecology**. Structure and function of running waters. California: Textbook, 1995.

ALMEIDA, T. S. *et al.* Impactos antrópicos e efeitos eco evolutivos sobre a biodiversidade. *In*: ARAÚJO, L. A. L.; VIEIRA, G. G. **Ensino da Biologia: uma perspectiva evolutiva**, v. II. Porto Alegre: Instituto de Biociências da UFRGS, 2021, cap. 349-396.

ARAÚJO, R. M. G. *et al.* Diagnóstico da Integridade Ambiental de trechos de um igarapé por meio de protocolo de avaliação rápida – Rio Branco, AC. **Revista Brasileira de Ciências da Amazônia**, v. 9, n. 4, p. 029-038, 2020.

ATTANASIO, C. M. *et al.* A importância das áreas ripárias para a sustentabilidade hidrológica do uso da terra em microbacias hidrográficas. **Bragantia**, v. 71, n.4, p. 439-501, 2012.

BEZARRA, P. C.; SOUZA, J.D. Urbanização de Tabatinga e impactos ambientais: estudo de caso do Igarapé Urumutum. **Revista GeoAmazônia**, v. 9, n. 17, p. 111-125, 2021.

BRASIL. **Lei n. 12.651**, de 25 de maio de 2012. Dispões sobre a proteção da vegetação nativa. Disponível em: https://www.planalto.gov.br/ccivil_03/_ato2011-2014/2012/lei/l12651.htm. Acesso em 13 set. 2024.

CALLISTO, M. *et al.* Aplicação de um protocolo de avaliação rápida da diversidade de habitats em atividades de ensino e pesquisa (MG-RJ). **Acta Limnologica Brasiliensia**, v.1, n.1, p. 91-98, 2002.

EPA. **Environmental Protection Agency. Biological criteria for the protection of aquatic life**. Division of Water Quality Monitoring and Assessment, Columbus, v. I-III, 120 p. Surface Water Section., 1987.

GARCEZ, L. N.; ALAREZ, G. A. **Hidrologia**. 2 ed. São Paulo: Edgar Blucher, 1988.

HANNAFORD, M. J.; BARBOUR, M. T.; RESH, V. H. Training reduces observer variability in visual-based assessments of stream habitat. **Journal of the North American Benthological Society**, v. 16, n. 4, p. 853-860, 1997.

INPA. Instituto Nacional de Pesquisas da Amazônia. **Estudo inédito aponta que as matas ciliares de pequenos rios de água preta apresentam maior diversidade evolutiva de espécies**. 2024. Disponível em: [Estudo inédito aponta que as matas](#)

ciliares dos pequenos rios de água preta apresentam maior diversidade evolutiva de espécies — Instituto Nacional de Pesquisas da Amazônia - INPA (www.gov.br). Acesso em: 13 set. 2024,

LEAL, G. L. R. **Paragominas** : a realidade do pioneirismo. 2 ed. Belém : Gráfica e Editora Alves, 2000.

LEMES, P. *et al.* Refinando dados espaciais para a conservação da biodiversidade. **Natureza & Conservação**, v. 9, n. 2, p. 240-243, 2011.

MITCHELL, G. Problems, and fundamentals os sustainable development indicators. **Sustainable Development**, v. 4, n.º 1, p. 1-11, 1996.

NESSIMIANN. J. L. *et al.* Land use, habitat Integrity and aquatic insect assemblages in CENTRAL Amazonian streams. **Hydrobiology**, n.615, p. 117- 131, 2008.

PRABHU, R.; COLFER, C. J. P.; DUDLEY, R. G. **Guidelines for developing, testing, and selecting criteria and indicators for sustainable forest management**. Toolbox series, n.º 1, Indonésia: CIFOR, 1999.

RODRIGUES, T. E. *et al.* **Caracterização de classificação dos solos do município de Paragominas, estado do Pará**. Belém: EMBRAPA, 2003, Documento 162.

RODRIGUES, R. S. *et al.* Análise dos efeitos de um evento extremo de chuva sobre o escoamento superficial em uma peque bacia hidrográfica rural Amazônica. **Revista Brasileira de Climatologia**, v.26, p. 368-392, 2020.

SANTOS, G. P.; OLIVEIRA, L. L.; MORTATI, A. F. Aplicação do índice de integridade do habitat e sua relação com a qualidade da água e com a hidrodinâmica de igarapés urbanos amazônicos. *In*: Simpósio brasileiro de Recursos Hídricos. 22, 2017. Santa Catarina. **Anais eletrônicos**. Disponível em: **ABRHidro - ANAIS - APLICAÇÃO DO ÍNDICE DE INTEGRIDADE DO HABITAT E SUA RELAÇÃO COM A QUALIDADE DA ÁGUA E COM A HIDRODINÂMICA DE IGARAPÉS URBANOS AMAZONICOS** (s/p) Acesso em: 13 set. 2024.

SANTOS, G. P. *et al.* Efeitos da Integridade ambiental da zona ciliar e sua influência na qualidade da água de igarapés urbanos em Santarém-PA, Amazônia, Brasil. **Revista Brasileira de Geografia Física**,v.14, n, 7, p. 4035 - 4055, 2021.

SEMAS. Secretaria de Estado de Meio Ambiente e Sustentabilidade; **Instrução Normativa n. 6**, de 9 de maio de 2011. Dispõe sobre procedimento de uso do solo através de autorização de supressão florestal nos imóveis e propriedades rurais na Amazônia Legal. Disponível em: **157.pdf (semas.pa.gov.br)**. Acesso em 14 set. 2024.

SILVA, I. B. B. *et al.* Caracterização hidrológica e ambiental de um apequena bacia do baixo rio Tocantins (AM) **Revista Ibero Americana de Ciências Ambientais**, v. 9, n. 6, p. 14-27, 2018.

SILVA, P. M. B.; SILVA, M. M. Igarapés impactos pela ação antrópica no município de Uruará, Pará. **Enciclopédia Biosfera**, v. 17, n. 31, p. 103-114, 2020.

TUNDISI, G. L.; TUNDISI, T. M. **Limnologia**. São Paulo: Oficina de Textos, 2008.

WATRIN, O. S.; ROCHA, A. M. A. **Levantamento da vegetação natural e do uso da terra no município de Paragominas (PA) utilizando imagens TM/LANDSAT**. Belém: EMBRAPA-CPATU, 1992.

ARTIGO 3

Analysis of three urban areas of the Paragominas creek regarding environmental Integrity, in the homonymous municipality, Pará, Brazil

ABSTRACT

Surface water in urban areas is directly affected by urban sprawl, especially through the loss of riparian vegetation and alterations to the physical meander structure. In this regard, there is no information on the anthropogenic impacts – A. I., and environmental conditions – E.C., of the Paragominas Creek, in the municipality of Paragominas, in the state of Pará. The aim of this research was therefore to generate data on three variables: urbanization, anthropogenic impacts, and environmental conditions in three urban areas and the consequences for the Paragominas Creek. The method used was exploratory research with qualitative and quantitative coverage, to measure the Habitat Integrity Index (HII). The data obtained and analyzed indicated that the three areas have values for both anthropogenic impacts ($A_1 = 4.4$; $A_2 = 3.8$; $A_3 = 5.3$) and environmental conditions ($A_1 = 3.4$; $A_2 = 0.4$; $A_3 = 5.1$), which affect the qualification of the HII. As a result, the Environmental Integrity index ($A_1 = 7.8$; $A_2 = 4.2$; $A_3 = 10.4$) was classified as "largely impacted" for the three areas. Therefore, municipal managers must urgently draw up plans for controlling, mitigating, and repairing actions in the urban area of the Paragominas creek.

Keywords: Urbanization. Anthropic Impacts. Environmental Conditions. Green Lake.

RESUMO

As águas superficiais nos espaços urbanos, são afetadas diretamente pela expansão urbana, especialmente pela perda da vegetação ciliar e alterações na estrutura física meandricas. Neste foco, a lacuna sobre os impactos antrópicos – I.A., e as condições ambientais – C.A., do Igarapé Paragominas, no município homônimo, estado do Pará, são inexistentes. Por isto, o objetivo desta pesquisa, foi a geração de dados acerca de três variáveis: urbanização, impactos antrópicos e condições ambientais em três áreas urbanas e as consequências sobre o igarapé Paragominas. O método utilizado foi de pesquisa exploratória com abrangência qualitativa e quantitativa, para a mensuração do índice de Integridade do Habitat - IIH. Os dados obtidos e analisados indicaram que as três áreas apresentam valores tanto para os impactos antrópicos ($A_1 = 4,4$; $A_2 = 3,8$; $A_3 = 5,3$), quanto para as condições ambientais ($A_1 = 3,4$; $A_2 = 0,4$; $A_3 = 5,1$), intervenientes na qualificação da IIH. Com isto, o índice de Integridade Ambiental ($A_1 = 7,8$; $A_2 = 4,2$; $A_3 = 10,4$), foi qualificado como "amplamente impactado" para as três áreas. Então, faz-se mister que os gestores municipais elaborem com urgência, planos de ações controladoras, mitigatórias e reparatórias na área urbana do igarapé Paragominas.

Palavras-chave: Urbanização. Impactos Antrópicos. Condições Ambientais. Lago Verde.

RESUMEN

Las aguas superficiales de las zonas urbanas se ven directamente afectadas por la expansión urbana, especialmente por la pérdida de vegetación ribereña y las alteraciones de la estructura física de los meandros. Teniendo esto en cuenta, hay una falta de información sobre los impactos antropogénicos y las condiciones

ambientales del Paragominas *Creek*, en el municipio de Paragominas, en el estado de Pará. Por lo tanto, el objetivo de esta investigación fue generar datos sobre tres variables: urbanización, impactos antropogénicos y condiciones ambientales en tres áreas urbanas y las consecuencias para las Paragominas *Creek*. El método utilizado fue la investigación exploratoria con cobertura cualitativa y cuantitativa, para medir el Índice de Integridad del Hábitat (IIH). Los datos obtenidos y analizados indicaron que las tres áreas presentan valores tanto de impactos antropogénicos ($A_1 = 4,4$; $A_2 = 3,8$; $A_3 = 5,3$) como de condiciones ambientales ($A_1 = 3,4$; $A_2 = 0,4$; $A_3 = 5,1$), que afectan la calificación del IIH. En consecuencia, el índice de integridad medioambiental ($A_1 = 7,8$; $A_2 = 4,2$; $A_3 = 10,4$) se clasificó como "muy afectado" en las tres zonas. Por lo tanto, los gestores municipales deben elaborar urgentemente planes de acciones de control, mitigación y reparación en el área urbana del arroyo Paragominas.

Palabras clave: Urbanización. Impactos Antropogénicos. Condiciones Medioambientales. *Green Lake*.

1 INTRODUCTION

Anthropogenic impacts such as urban sprawl have a strong influence on the patterns of aquatic ecosystems in these areas, whether on a global or local scale (Hamid *et al.*, 2019). The environmental status of water bodies has been altered by human activities and the growth of urban areas, as there have been territorial biophysical modifications, as reported in a study conducted in Colombia (Pazos; Chamorro, 2021).

Such impacts in urban areas lead to alterations and the creation of new landforms and soil that cause severe changes to water sources and, consequently, to the aquatic habitat (Luz *et al.*, 2015). When this occurs in surface waters such as streams, the suppression of riparian vegetation causes disharmony in the water-land system, which until then had been represented by them because it leads to erosion, a drop in nutritional supply, soil compaction and even decreases the water cycle (Santos *et al.*, 2021).

When urban expansion is poorly planned or occurs haphazardly, it presents numerous variables such as suppression of riparian forest, generation of waste, construction of architectural units on the banks of water bodies, causing negative effects and compromising social uses such as fishing (Bezerra; Souza, 2021). In this context, streams are extremely sensitive environments whose environmental conditions have been modified by anthropogenic impacts in the urban context, especially siltation and sewage disposal (Pimentel *et al.*, 2021).

These two factors, anthropogenic impacts and environmental conditions, are real and must be analyzed, studied, monitored, described and discussed with society and management bodies and, in order to identify them more efficiently and effectively, the application of a rapid assessment protocol is the most accessible and selective way of identifying the variables that make up the two factors (Dias; Rubim, 2021). This type of assessment allows for the generation of qualitative and quantitative information that is extremely important for the conservation and monitoring of streams (Araújo *et al.*, 2020).

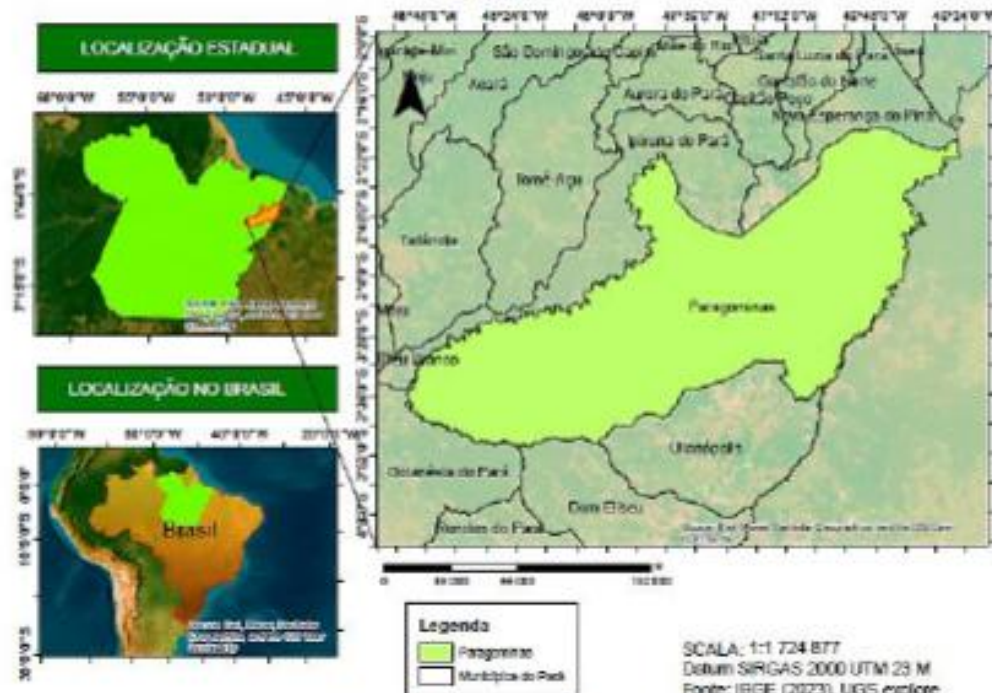
All these problems justify this research, the relevance of which is evidenced by the lack of information of this nature on the urban stretch of the Paragominas creek. The aim was therefore to generate data on anthropogenic impacts and environmental conditions from the Constantino Pereira do Sacramento highway to Padre Castilho street, where the stream flows into the Uraim River. As a result, Paragominas' water management bodies will have up-to-date information on the creek with the same name, in its urban stretch.

2 MATERIAL AND MÉTODS

2.1 PHYSIOGRAPHY OF THE MUNICIPALITY

The municipality of Paragominas (Figure 1), which belongs to the southeast of Pará, is located, in a straight line, 316 km from the capital of the state of Pará, Belém, between the parallels of 2°38' and 3°40' - S, and 46°27' and 48°50' E Greenwich (Conceição *et al.*, 2020). It came into being in 1965, as a result of Law No. 3.235, published on January 4th of that year, during the government of Mr. Jarbas Gonçalves Passarinho, who signed it (Pará, 2023).

Figure 1 - Location map of the municipality of Paragominas, southeast of the state of Pará, Brazil.



Source: Prepared by Silva, G. R.

This municipality can be reached via two access roads: BR - 010, also known as Belém-Brasília, and PA 125. The soil is classified as Latossolo Amarelo with a clayey texture, i.e., clay loam and Plintossolo (Rodrigues *et al.*, 2003). The vegetation is made up of Ombrophilous Forest, which is presented in two versions: 1) open because the trees are distant, with a low density of shrubs and lianas (Watrin; Rocha, 1991).

The contribution to the rainfall is low, so there are few rainy periods; 2) the vegetation is perenefoliated with extensive leaves, with alluvial sub formation, under montane and with the presence of lowlands. As a result, the rainy periods are more intense (Pará, 2023). The climate classification, according to Köppen, is Aw: tropical rainy, with a well-defined dry period between June and November. Annual rainfall averages 1,743 mm between December and May.

The Paragominas stream serves the rural community and therefore has a high number of dams (± 11) that serve as reservoirs for cattle watering/agricultural irrigation. In addition, this body of water is a right-bank tributary of the Uraim River, which also runs through the urban area, since the slope of this stream crosses the urban area of this municipality (Rodrigues *et al.*, 2020).

2.2 METHOD

The method used was exploratory, observational in nature and qualitative-quantitative in scope (Callisto *et al.*, 2002) which, combined with the Rapid Habitat Assessment Protocol - RHAP, increases the effectiveness of the analysis of the two variables (anthropogenic impacts – A. I., and environmental conditions – E.C.) in the areas belonging to the Uraim River micro-basin. Therefore, the use of this type of protocol generates more reliable information about the real state of the water body, as well as the surrounding areas (Mitchell, 1996).

To complete the HII, the study of anthropogenic impacts on the water body was associated with the aim of generating data for municipal management and contributing to effective environmental monitoring, with an assessment of the habitat, which, depending on the environmental conditions it presents, could be the greatest cause/threat of species extinction (Almeida *et al.*, 2021).

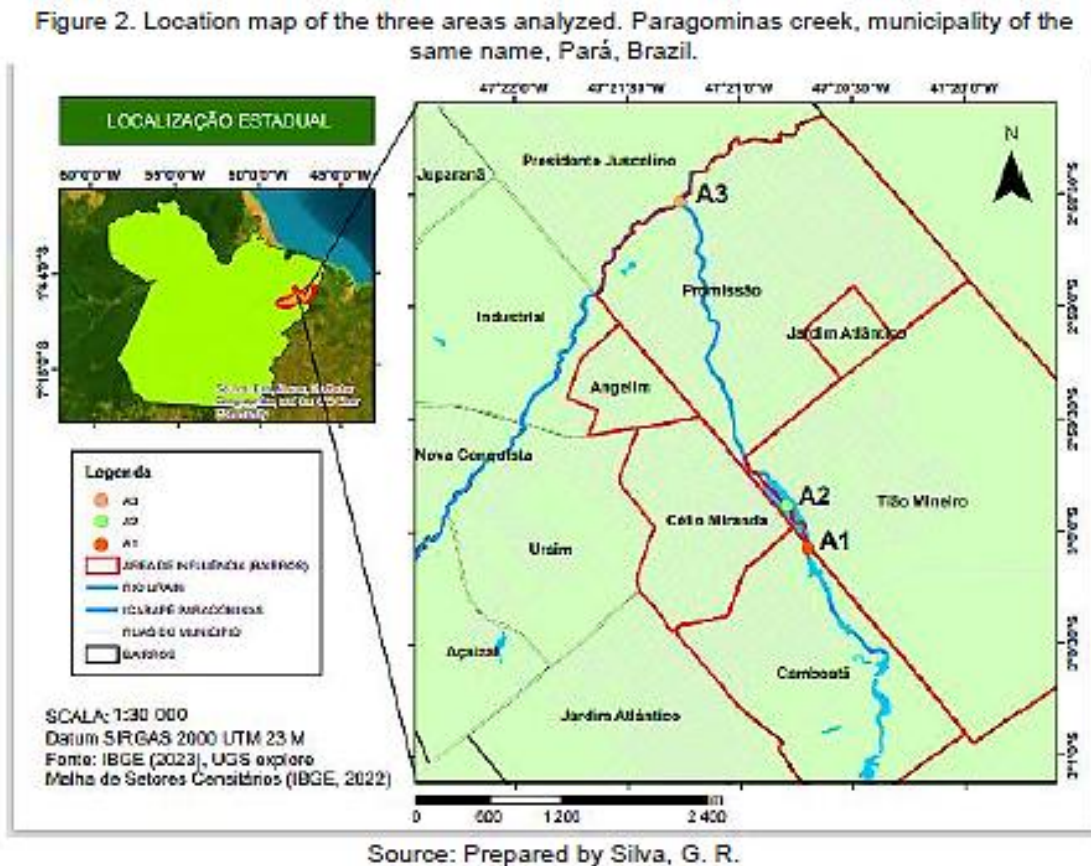
For this reason, this association became the justification for using it in this research, as it will allow and contribute to future studies on this stream, regarding the maintenance and environmental conservation of this water body and associate it with the evolution or involution of the habitat.

With these two pieces of information, the development of measures to monitor and control the quality of the environment, by the bodies that manage water resources in the municipality of Paragominas, as well as the application of mechanisms for environmental quality and, consequently, habitat, in this Paragominas creek, will allow for more effective management and constant monitoring of both the quality of the water and the conservation of this site.

2.4 SELECTED AREAS

Three component areas of the urban landscape were selected, in the upstream-downstream direction, based on the growth of urbanization, whose reference point is the PA 125 Highway, and the direction, upstream → downstream, left bank, A1, bordered by the Camboatã, Célio Miranda, Guanabara and Promissão neighborhood's; right bank. Green Lake, A2, bordered by the Tião Mineiro, Parque IV, Clube do Cavalo and Promissão neighborhood, on Padre Castelo street, there is a bridge (length = 10.2 m; width - 8.5 m) that has been raised to continue the flow of vehicles from the latter two neighborhoods. The flow of water passes under this

concrete structure and flows into the Uraim River, 400 m from this road platform, and constitutes the A3 (Figure 2).



2.4 OBTAINING DATA

2.4.1 Primary

To obtain this data, six on-site visits were made (two for each selected area). They were used for observation, visual identification, and textual composition of anthropic impacts (A.I.) and environmental conditions (E.C.), as well as the construction of a photographic memorial. They were then placed in two tables. In Table 1, data was entered for the seven parameters related to the A.I. with the guidelines required by the Ohio Environmental Protection Agency (EPA, 1987).

Table 1. Seven evaluation parameters for anthropogenic impacts – A.I., Paragominas creek, municipality of the same name, Pará, Brazil.

Location:
Date of collection:
Time on day of collection:
Mode of collection:
Type of Environment:
Average Width:
Average Depth:
Average Water Temperature:
Parameter 1: Presence/absence of allochthonous material
Parameter 2: Physical changes in the meander of the watercourse
Parameter 3: bank stability
Parameter 4: Type of land use
Parameter 5: Conservation status of the surrounding vegetation
Parameter 6: erosion near and/or on the bank of the water body
Parameter 7: Anthropogenic changes

Adapted from Callisto *et al.* (2002).

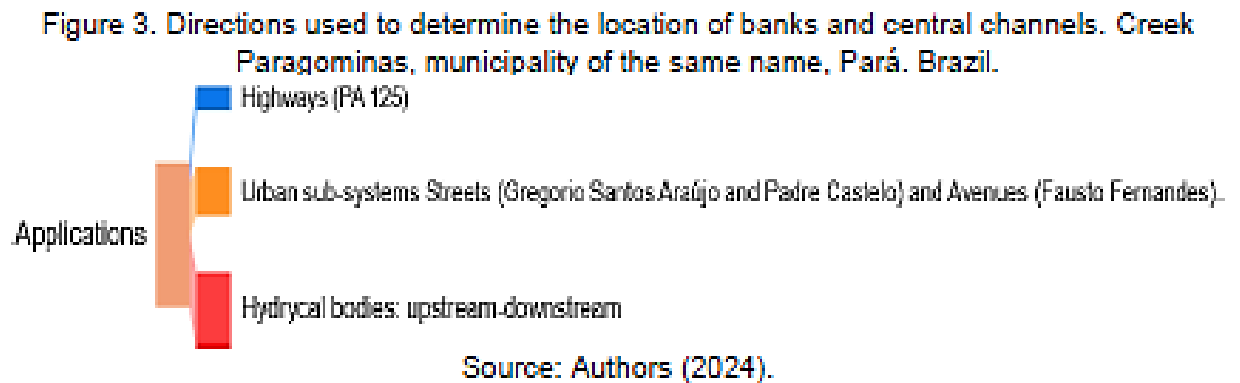
Table 2 shows the data obtained for the E. C. For this action, the quantitative similarities were maintained, i.e., seven, in relation to the number of parameters used for E.C. These are part of the 21 parameters identified by Hannaford (1997). This selection is justified in order to better analyze and reflect on the real condition of the Paragominas creek.

Table 2. Parameters for assessing the current environmental condition - E. C. Paragominas Creek, municipality of the same name, Pará, Brazil.

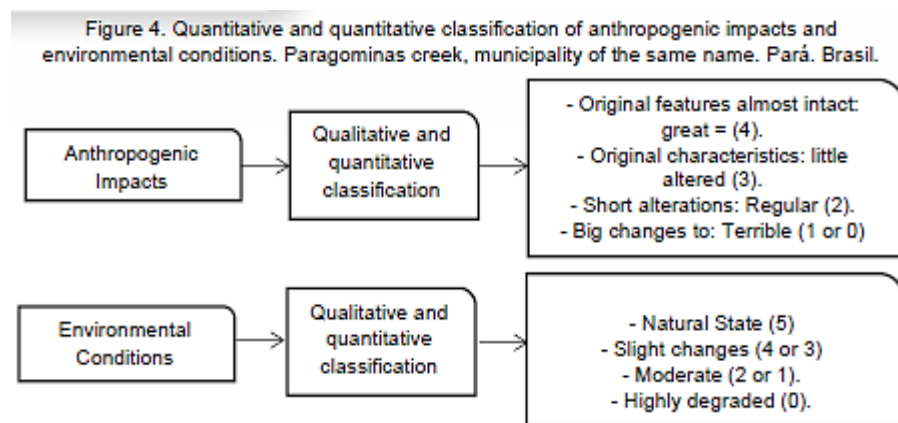
Parameter 1: riparian vegetation at a distance of 10 m from the water's edge
Parameter 2: changes in the water body channel
Parameter 3: water flow
Parameter 4: maintenance of the riparian forest
Parameter 5: extension of riparian forest
Parameter 6: presence of aquatic plants
Parameter 7: type of substrate

Adapted from Callisto *et al.* (2002).

In these two tables, the allocated data, associated with the directions and directions, allowed greater understanding in the discussion about what was perceived and identified in the three areas analyzed (Figure 3).



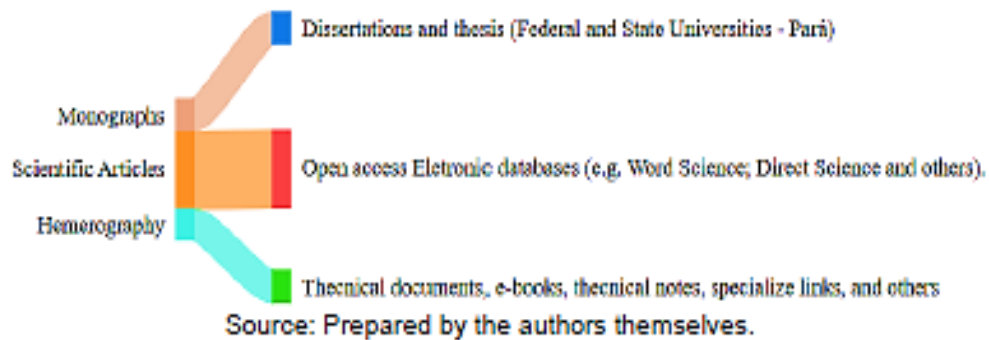
After allocating the data obtained, a qualitative and quantitative assessment was made using the terms and values employed by Hannaford *et al.* (1997), with ways used to HII (Figure 4).



2.4.2 Secondary

To obtain this data, various forms of literature related to the subject of this research were selected, and research was conducted at higher education institutions and electronic links to specialized journals (Figure 5).

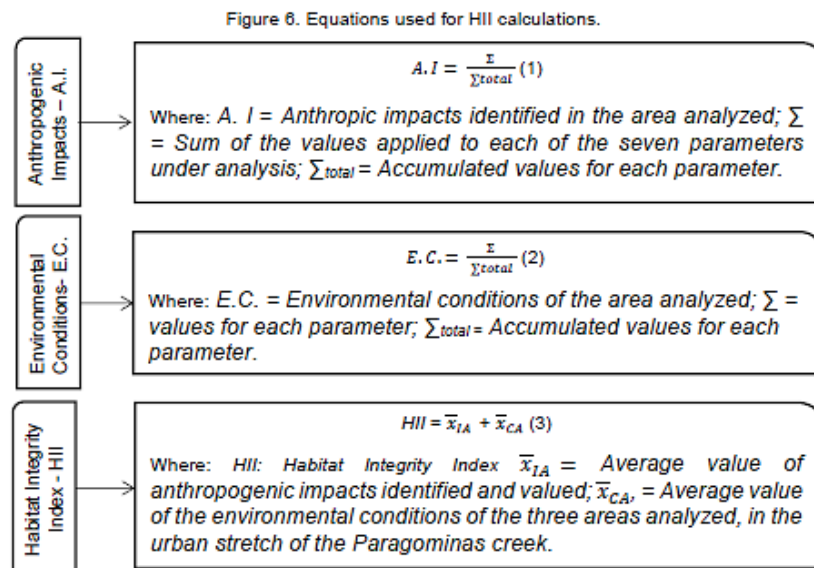
Figure 5. Types of literature and the places where they were selected to make up the corpus of this research.



A period was not established because pioneering literature was used (Allan, 1995; Mitchell, 1996; Prabhu *et al.*, 1996; Watrin; Rocha, 1991). The aim of this was to provide a better basis for the evolution of the subject of this research. However, among the literature selected, priority was given to publications that had taken place in the last five-year period (2020-2024). This period allowed for a better characterization of the application of the HII.

2.5 CALCULATIONS MADE

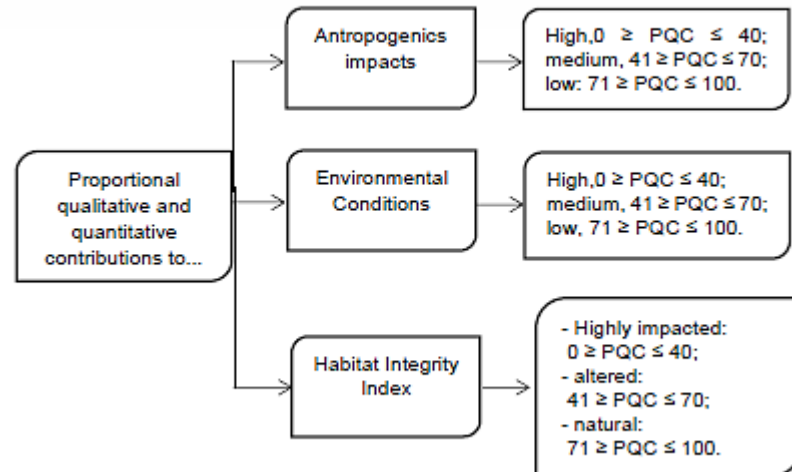
In order to make the calculations needed to obtain the data for A.I., E.C. and HII, it was necessary to apply three equations (Figure 6).



Source: Prepared by the authors themselves.

To check the quality of the IHI, based on the A.I., and E.C., we adapted the Nessimian *et al.* scale (2008). For greater veracity, this scale was associated with the metrics applied by Callisto *et al.* (2002), where: the qualitative and quantitative aspect of HII (Figure 7).

Figure 7. Proportional qualitative and quantitative contributions (PQC) of anthropogenic impacts (A.I.) and environmental conditions (E.C.) to the Habitat Integrity Index (HII). Creek Paragominas, municipality of the same name, Pará, Brazil.



Adapted from Nessimian *et al.* (2008)

3 RESULTS

3.1 A1 - CONFLUENCE OF PA 125 HIGHWAY WITH GREGÓRIO SANTOS ARAÚJO STREET, CAMBOATÃ NEIGHBORHOOD

This area is located on the left bank of the PA 125, in the N → S direction, at the back of the Camboatã neighborhood (Figure 8a), which is already fully urbanized and, in this location, has a large number of macrophytes (Figure 8b), and "macrophyte cleaning" (Figure 8c), as well as dredging the bottom, depositing it on the marginal vegetation that still exists.

Figure 8. a) PA-125 highway. A; b) presence of aquatic macrophytes and marginal vegetation; c) "clearing" of the riparian forest, removal of aquatic vegetation and dredging with exposure of the bottom substrate on the bank itself. Paragominas creek, municipality of Homonym, Pará, Brazil.



Source: Prepared by the authors themselves.

3.1.1 Anthropogenic impacts

In this area, the perception of these impacts indicated that, of the seven parameters analyzed, most of them ($n = \text{Five}$; 71.4%) had accumulated values equal to four, and this contributes to the characterization of environmental degradation from these impacts, since they modified some of the morphophysiological aspects such as the natural meander, the temperature of the water body and the depth (Table 3).

Table 3. Qualitative and quantitative identification of A₁ in terms of anthropogenic impacts – A.I. Paragominas creek, municipality of the same name, Pará, Brazil.

Location: Confluence of the PA 125 highway with Gregório Santos Araújo street, Camboatã neighborhood.			
Given by coleta: 05/08/2024			
Time on day of collection: sunny day (30° C), winds with $v = 1.5$ m/s, direction northwest → southwest.			
Collections Methods: Observational, with the production of a photographic memorial.			
Type of Environment: Urbanized, with a lack of tree and shrub vegetation and the presence of herbaceous plants.			
Average width (m): $\bar{x} = 41.7$ m			
Average Depth (m): $\bar{x} = 1.4$ m			
Average water Temperature (°C): $\bar{x} = 34.5$			
Parameter 1: presence/absence of allochthonous material.			
PA 125 Highway: the water's edge has been leveled for road paving, thus the presence of allochthonous material.	Marginal residences: presence of allochthonous material since land has been cleared and "backyards" have been created in the study area.	Rua Gregório Santos Araújo: asphalt paving with deposition of allochthonous material for waterproofing.	There is allochthonous material on all the banks, as architectural constructions still occur in this area.
(1)	(1)	(1)	(1) $\Sigma = 4$
Parameter 2: physical changes in the meander of the watercourse.			
The lake formed to the left of the PA 125 highway; the meander of the water body has undergone changes (widening).	On the right bank, there is an area without social servitude, 10 m away, without any vegetation cover, which contributes to the physical deformity of the lake.	Widening under the bridge on the PA 125, where the water flow has a backwater area.	After the bridge, on the right bank of the PA 125, there has been grounding, which has reduced the drain's output.
(1)	(1)	(1)	(1) $\Sigma = 4$
Parameter 3: bank stability			
In the direction of PA 125, ME: there is an imminent risk of marginal erosion, which is on average 23.5 m away.	In the direction of M → J, ME, there is almost no vegetation protection and a high risk of erosion, as there are "residential backyards".	On street Gregório Santos Araujo, the stability of the bank is partial, as there are grasses providing the necessary support.	Also on this street, the land without social servitude, which presents an imminent risk of erosion
(1)	(1)	(2)	(1) $\Sigma = 5$

Parameter 4: type of land use			
In the M → J direction, MD, implementation and paving of roads, sidewalks and sidewalks.	In the W → E direction, asphalt paving for the urban subsystem: two-way access road.	In the same direction, access was made to the PA 125 highway from the Camboatã neighborhood.	The natural progress of the watercourse was earthed and diverted for architectural constructions.
(1)	(1)	(1)	(1) Σ = 4
Parameter 5: conservation status of the surrounding vegetation			
In the area constituted and identified here as A ₁ , the surrounding vegetation has been suppressed.	The suppression of the surroundings vegetation occurred both on the banks of the PA 125 highway and in residential areas.	In the ME, direction M → J, the secondary tree context is scarce.	Also in this sense, but in the MD, the vegetation consists of herbaceous plants (grasses, Poaceae Family).
(1)	(1)	(1)	(1) Σ = 4
Parameter 6: erosion near and/or on the bank of the water body			
PA 125 highway, direction N → S, ME, the bank of the creek is below the level of the highway, with an imminent risk of erosion, due to the scarcity of vegetation.	In the water body, direction M → J, MD, the backyards located in the study area do not present an imminent risk of erosion.	In Rua Gregório Santos de Araujo, the marginal embankment presents an imminent risk of erosion.	No erosion was noticed near the banks.
(2)	(1)	(1)	(2) Σ = 6
Parameter 7: anthropogenic changes			
Direction N → S: Marginal embankment with narrowing of the channel; settlement of the PA 125; construction of a concrete bridge over the stream bed.	In the M → J direction, the settlement of the Camboatã neighborhood caused the watercourse to be earthed and diverted.	The slope that exists 20 m from the confluence of Gregório Santos de Araújo Street with the P125 leads rainwater to the creek, causing flooding.	There is a canal embankment that has caused the detour of the creek's source, on the MD, heading N → S, PA 125 Highway.
(1)	(1)	(1)	(1) Σ = 4
Σ_{total} = 31			

Source: Prepared by the authors themselves.

3.1.2 Environmental Conditions – E.C.

Analysis of these conditions in this area showed that three parameters (42.8%) had zero values, which contributed to an extremely negative rating of the habitat's environmental condition (Table 4).

Table 4. Qualitative and quantitative identification of the A₃ in terms of its environmental condition - E.C. Paragominas creek, municipality of the same name, Pará, Brazil.

Parameter 1: riparian vegetation at a distance of 10 m from the water's edge			
Degraded.	In areas prior to this, there is still vegetation at this distance.	The backyards of the architectural units with social servitude show a scarcity or substitution of this vegetation.	Analysis of the contour of the area analyzed at this distance indicates that there has been no conservation of this vegetation.
(0)	(0)	(0)	(0) $\Sigma = 0$
Parameter 2: changes in the water body channel			
Channel widening; loss of original bank.	In the central channel, near the bridge, there is a narrowing of the channel.	An area without social servitude, located at the MD of the body of water, is landfilled for future architectural development.	Drainage practices conducted both in the channel and on the banks to increase the capacity to receive and store rainwater.
(1)	(0)	(1)	(1) $\Sigma = 2$
Parameter 3: water flow			
In the M → J direction, backwaters are frequent due to the presence of aninga islands - <i>Montrichardia arborescens</i> Schott. Família Araceae (Cruz <i>et al.</i> , 2008).	In the central channel, in the same direction, water flow is slow, contrary to the general rule.	In the transition of the water flow under the bridge (source) there are two routes for this flow.	At the outlet of the body of water (drain), it can be seen that the flow faces obstacles under the bridge, as the obstacles are the widths of the supporting pilasters.
(1)	(1)	(1)	(1) $\Sigma = 3$
Parameter 4: maintenance of the riparian forest			
There is no maintenance of the riparian forest in this area	ME, direction N→S, PA 125 highway, total suppression on A3.	MD, direction M→J, "backyards" have been planted on the site of the riparian forest.	Near the fountain, and to the side of Gregório Santos Araújo Street, there was also total suppression.
(0)	(0)	(0)	(0) $\Sigma = 0$
Parameter 5: extension of riparian forest			
(0)	(0)	(0)	(0) $\Sigma = 0$
Parameter 6: presence of aquatic plants			
On Highway Pa 125, ME, the presence of aquatic plants is frequent. In particular, water hyacinth (<i>Eichhornia</i> spp)	In the Gutter Central, towards M → J, in the initial stretch, the presence of aquatic plants is frequent.	In the MD, towards M → J, aquatic plants are scarce.	On the parallel with Gregório Santos Araújo Street, near the fountain, aquatic plants are more frequent.
(2)	(2)	(4)	(3) $\Sigma = 11$

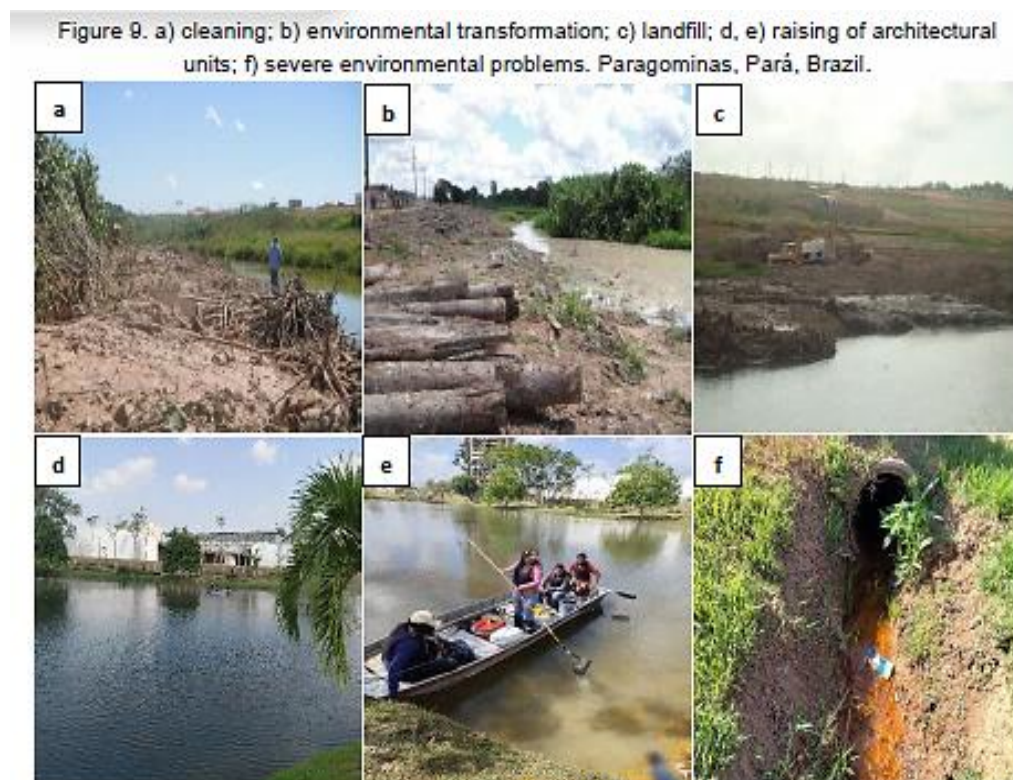
Parameter 7: type of substrate			
On the PA 125 highway, direction N → S: clayey sand with leaf litter.	Central ME, direction M → J, sandy clay with branches, leaves, and logs.	Gutter, MD, direction M → J, sandy silt, with leaf litter and logs.	Near the fountain, muddy, with palisade material.
(2)	(2)	(2)	(2) $\Sigma = 8$
$\Sigma_{total} = 24$			

Source: Prepared by the authors themselves.

When calculating the HII of this area, the qualitative classification, according to the Calisto *et al.* scale (2002), is "highly impacted". The quantitative value associated with this qualification was the lowest (7.8), as the average value for A.I. (4.4) was higher than that found for E.C. (3.4).

3.2 A2 – GREEN LAKE

The area under analysis is located to the left of PA 125 highway. It arose from a municipal action to clean up the area (Figure 9a), which had been transformed into an open-air dump. To this end, the municipal administration at the time intensified the environmental transformation (Figure 9b), landfilling (Figure 9c), and the erection of architectural units (Figures 9d;9e). However, the reception of domestic effluent still presents severe environmental problems (Figure 9f).



Source: Prepared by the authors themselves.

3.2.1 Anthropogenic impacts

For this topic, in this area, the reports of its genesis are in line with the visual observations because anthropogenic impacts have already altered both the soil and the aquatic infrastructure in this area, this is notorious since one of the parameters obtained a quantitative equal to 11 (Table 5).

Table 5 - Qualitative and quantitative identification of anthropogenic impacts – A. I., on A₂.
Paragominas creek, municipality of the same name, Pará, Brazil.

Location: Green Lake.			
Given by coleta: 03/09/2024.			
Time on day of collection: Sun, 30°C, wind 0.5m N→S direction.			
Modo de coleta: Observational, with the production of a photographic memorial.			
Type of Environment: urbanized area, with architectural units that are exclusively residential or exclusively commercial (e.g. garage-workshop for public transport) or mixed (commercial on the ground floor and residential on the upper floor). Receiver of effluent from the Tião Miranda, Camboatã and Célio Miranda neighborhoods.			
Average width (m): $\bar{x} = 58.9$			
Average depth (m): $\bar{x} = 3.5$			
Average water temperature (°C): $\bar{x} = 33.5$			
Parameter 1: presence/absence of allochthonous material.			
They can be seen along the entire length of the waterfront, whether left or right.	On the right bank, after the bridge, there are stones that are alien to the original formation of the body of water	The central channel in this area has been greatly altered by the total removal of the original vegetation, earthworks and the construction of "islets" with alien materials.	On the left bank, there is also the presence of allochthonous material, mainly the construction of a culvert, which acts as a dumping ground.
(1)	(1)	(1)	(1) $\Sigma = 4$
Parameter 2: physical changes in the meander of the watercourse.			
Since receiving the water that flows under the PA 125 bridge, the meander has become wide and irregular.	Just after the PA 125 highway bridge, the physical space widened a little but lost its sinuosity.	In the middle third, the meander was completely widened. Sinuosity absent.	In the upper third, in the M → J direction, there was grounding which reduced the width of the natural meander.
(1)	(1)	(1)	(1) $\Sigma = 4$
Parameter 3: bank stability			
On the left bank, parallel to the PA 125 highway, the road has been paved and the small slope has been covered with grass.	On the right bank, the changes have been even greater: in addition to the paving, "snack stalls" have been erected.	After the bridge, in the upper third, the left bank was earthed, paved and grassed, which brought the banks into the new central channel.	On Fausto Fernandes Avenue, where the stability of the bank is maintained by grasses on the slope.
(1)	(1)	(1)	(1) $\Sigma = 4$
Parameter 4: type of land use			
The areas around Green Lake, on the sides, are currently paved (asphalt and cement)	In the M → J direction, there is Av. Deputado Fausto Fernandes, where there is a concrete bridge that allows access to the Flamboyant neighborhood.	Still in this direction, on the right bank, there are architectural units with land, parking and businesses.	The existing vegetation is derived from types that nourish ruminants such as <i>Brachiaria</i> spp.
(1)	(1)	(1)	(1) $\Sigma = 4$

Parameter 5: conservation status of the surrounding vegetation			
Since the modification of the meander, there has been intense vegetation suppression, thus the loss of the natural vegetation of the APP.	From the beginning of the bridge over the Paragominas stream, at the junction with Gregório Santos Araújo Street, MD, the trees are all native.	On the ME, in the direction of M → J, the Tião Mineiro neighborhood has been built up with three residential complexes, and the natural vegetation has been completely suppressed.	At the back, in addition to landfill and vegetation suppression, architectural units were erected for a shopping mall.
(1)	(1)	(1)	(1) $\Sigma = 4$
Parameter 6: erosion near and/or on the bank of the water body			
A small erosion was observed on the left bank from the drain, in the M → J direction.	From the drain to the central bridge, the anthropogenic slope has been covered with grass, which mitigates erosion in the ME.	On the segment of the MD parallel to the PA 125 highway, a slope was also installed with the same vegetation cover.	At the exit to Avenue Fausto Fernandes, ME, erosion occurs because this is where a culvert was installed
(2)	(1)	(1)	(0) $\Sigma = 3$
Parameter 7: anthropogenic changes			
ME: meander alteration; CC, also; MD, reduced by landfill and the emergence of the Camboatã neighborhood and paving of the PA 125 highway.	Drainage of domestic effluents has 13 points (culverts) that flow into the bed of the Paragominas Creek (Green Lake).	In the ME, structures (stalls) were set up for various types of marketing. The sewage system ends inside the Green Lake.	Landfill of a large area of the MD, with a narrowing of the central channel, and there they installed a leisure area for the population of Paragominas.
(1)	(1)	(1)	(1) $\Sigma = 4$
$\Sigma_{total} = 10$			

Source: Prepared by the authors themselves.

3.2.2 Environmental condition – E.C.

The data obtained and analyzed for E.C. in this area indicated that the environmental transformations caused on the banks and in the meander of the Paragominas creek in this area have altered the integrity of the habitat (Table 6).

Table 6. Qualitative and quantitative identification, A₂, of the environmental condition
– E. C., of the Paragominas creek, municipality of the same name, Pará, Brazil.

Parameter 1: riparian vegetation at a distance of 10 m from the water's edge			
In this area, the original vegetation has been completely removed.	This occurred both in the M → J direction and in the W → E direction.	Not even floodplain Brachiaria is found in this area.	In the area belonging to the lake, the marginal vegetation consists of grass that support the slope, and sparse shrub and tree components.
(0)	(0)	(0)	(1) Σ = 1
Parameter 2: changes in the water body channel			
The slope of this body of water, which used to be sinuous, is now shapeless.	The bottom substrate was clayey (464.4 g/kg) to very clayey (630 g/kg) ¹ .	In the M → J direction, there is a raised roadway in the middle of the canal, which is drained by two culverts.	On the left bank, the embankment of the channel has created an islet, a detour with allochthonous material.
(0)	(0)	(0)	(0) Σ = 0
Parameter 3: water flow			
It can be seen that the installation of a footbridge over the water body under study has compromised the water flow.	Spring in this area, which has a large amount of aquatic vegetation, which compromises the water flow.	The concrete bridge that allows water to flow between source and drain has many obstacles underneath it.	The water flow is only partially restored near Avenida Deputado Fausto Fernandes, where the canal has narrowed.
(0)	(0)	(1)	(1) Σ = 2
Parameter 4: maintenance of the riparian forest			
Due to the urbanization works on this part of the Paragominas creek, there has been no maintenance of this vegetation, whether to the north, south, east, or west.			
(0)	(0)	(0)	(0) Σ = 0
Parameter 5: extension of riparian forest			
Due to the urbanization works on this part of the Paragominas creek, there has been no maintenance of this vegetation, whether to the north, south, east, or west.			
(0)	(0)	(0)	(0) Σ = 0
Parameter 6: presence of aquatic plants			
In this area, the management bodies order "daily cleaning of aquatic vegetation" to beautify the site. This compromises the physiological structure of the aquatic ecosystem, such as the nutritional cycle.			
(0)	(0)	(0)	(0) Σ = 0
Parameter 7: type of substrate			
Due to the lack of previous data on this parameter, it is not possible to establish a comparison with what was obtained in the background granulometry. As this is Anthropic Yellow Latosol, the textural classification was clayey (upstream) and very clayey (near Avenue Fausto Fernandes deputy).			
(0)	(0)	(0)	(0) Σ = 0
Σ = 3			

¹Particle size classification conducted by the Solos & Plants laboratory, with professional registration in this area.

3.2.3 Habitat Integrity Index

The HII classification of this area, according to that proposed by Calisto *et al.* (2002), is "highly impacted". The basis for this adjective is the values for the qualitative

and quantitative proportion of A.I. (3.8) and E.C. (0.4) for A₂. As a result, the value for HII (4.2) is low.

3.3 A3 - OUTFLOW OF THE PARAGOMINAS CREEK, RIGHT BANK OF THE URAIM RIVER

This area is located on Rua Padre Castelo and is 19.6m from Barão de Araruna street, Promissão neighborhood. The source (10a) comes from Green Lake, and this water flow passes under the concrete bridge (Figure 10b), which is 12.4m long and 8.5m wide. The movement of the body of water continues from upstream to downstream until it flows into the River Uraim (Figure 10c).

Figure 10. a) Displacement of the water flow from Green Lake to the Padre Carvalho street bridge; b) bridge under which the water flow moves; c) outflow of the Paragominas creek into the Uraim river, municipality of the same name, Pará, Brazil.



Source: Prepared by the authors themselves.

3.3.1 Anthropic Impacts

Analysis of the data obtained indicated that the numbers entered for each parameter were more evenly distributed between four and seven, with a greater presence of grade five (n = three; 42.8%), which shows a balance in relation to the cause-effect of anthropogenic impacts on HII (Table 7).

Table 7. Qualitative and quantitative identification of anthropogenic impacts – A.I., Paragominas creek. Municipality of the same name, Pará, Brazil.

Location: Padre Castelo street.			
Given by coleta: 09/10/2024			
Time on day of collection: Lots of sunshine.			
Collection method: Observational, with the production of a photographic memorial.			
Type of Environment: Secondary vegetation, with fruit crops (<i>Musa</i> sp. Musaceae Family; Coconut - <i>Cocos nucifera</i> , Arecaceae Family) on both banks, just after the bridge span. In the previous area, there is an area with agricultural plantations (<i>Phaseolus</i> sp. Fabaceae Family).			
Average width (m): $\bar{x} = 1,3$ m			
Average depth (m): $\bar{x} = 1,6$ m			
Average water temperature (°C): $\bar{x} = 30,2$ °C.			
Parameter 1: presence/absence of allochthonous material.			
Presence of this material from the bridge to 200 m from the drainage point.	In the M → J, MD direction, the architectural units located at an average of 40 m determined the entry of this type of material.	In the same vein, but in the ME, there are also architectural units, as well as leisure areas less than five meters from the shore.	The closer you get to the drainage area; the secondary vegetation starts to flourish again.
(1)	(1)	(1)	(2) $\Sigma = 5$
Parameter 2: physical changes in the meander of the watercourse.			
In the direction of M → J, MD, near the bridge, there is a ground, which narrows the central channel.	Under the bridge, in the same direction, the slopes supporting the bridge, on both banks, also cause narrowing in the central channel.	After the bridge, the amount of sedimentation deposited in the central channel causes the depth to decrease.	The narrowing of the central channel extends to the final area of the creek under study.
(1)	(1)	(1)	(1) $\Sigma = 4$
Parameter 3: bank stability.			
In the M → J direction, the vegetation in front of the bridge provides marginal stability.	At 10 m, in the same direction, MD, there is a sparse and scarce presence of Palmaceae, which do not guarantee marginal stability.	Just after the bridge, in the same direction and on the same bank, there is an imminent risk of marginal erodibility due to the type of vegetation cover.	After the urbanized and altered areas, the vegetation already provides marginal stability.
(1)	(1)	(1)	(2) $\Sigma = 5$
Parameter 4: type of land use			
The use and occupation of the land, in the direction of M → J, in both ME and MD, near the bridge, was occupied by architectural units with social servitude.	In the E → W direction, there is a presence of asphalt paving with sidewalks.	In the M → J, ME direction, in addition to the architectural units, there are ornamental and agricultural crops.	Near the drainage area, the secondary vegetation remains intact, i.e., without anthropogenic alterations.
(1)	(1)	(1)	(2) $\Sigma = 5$
Parameter 5: conservation status of the surrounding vegetation			
In the direction of M → J, on both banks, just after the areas with architectural units, the	In places prior to the drain (10 m), there was no conservation of the surroundings, but rather	Based on the agricultural crops that have replaced the native vegetation, these are conserved.	In the areas where the vegetation fragment occurred, one of the residents

The last 10 m shows a replacement of it with conservation of this agricultural crops and vegetation, the formation of recreational areas. tries to recover the surrounding vegetation with tree plants (e.g., Citrus sp. Family Rutaceae).

(1)

(1)

(1)

(3) $\Sigma = 6$ **Parameter 6: erosion near and/or on the bank of the water body**

In the direction of M → J, ME, erodibility near the bank is imminent, as the slope is steep in relation to the water depth and the vegetation cover is scarce.

Along the same lines, in the area intended for recreation as soon as it approaches the water's edge, landfill can be an imminent factors in erosion.

In the same vein, but in the MD, the presence of backyards without vegetation also increases the risk of erosion.

In the drainage area, there is no prospect of erosion either near or on the bank.

(1)

(1)

(1)

(4) $\Sigma = 7$ **Parameter 7: anthropogenic changes**

In the M → J direction, anthropogenic changes have occurred due to urbanization and changes in land use and occupation.

The meander of the body of water shows areas of decreasing width as well as depth.

In the channel at the level of the source and the drain, the existence of alluvium resulting from the process of earthworks on the banks.

On the sloping streets that flow into the Paragominas stream, domestic effluent is notorious.

(1)

(1)

(1)

(1) $\Sigma = 4$ $\Sigma = 36$

Source: Prepared by the authors themselves

3.3.2 Environmental condition

The data obtained and analyzed indicated that in C. A., the majority (n = five; 71.4%) of the parameters (One to four) obtained similar scores, when compared to the other three (Five, Six and Seven), the variation was more effective, between four and seven (Table 8).

Table 8. Qualitative and quantitative identification, in A₃, of the environmental condition – E. C. Paragominas creek, municipality of the same name, Pará, Brazil.

Parameter 1: riparian vegetation at a distance of 10 m from the water's edge			
Consider the area where AI is not the object of analysis, the vegetation is conserved, even at a secondary stage.	This is observed only in the drainage area, and the perception obtained for the ME in the M → J direction is considered.	On the other hand, the MD, in the same direction, has less conservation.	Currently, in the area before the fountain (below the concrete bridge), at 100 m, the ME has more abundant vegetation such as marsh Brachiaria.
(1)	(1)	(1)	(2) $\Sigma = 5$
Parameter 2: changes in the water body channel			
From the 100m access to the fountain, it was observed that the MD, from 50m,	In the ME, the first architectural units, only from 30 m near the source.	On both banks, the vegetation has expanded into the channel, causing it to narrow.	All this also happens from the drain, i.e., after the bridge. And it extends up to 100 m, reaching the area where

already presents architectural units.			the stream flows into the Uraim River.
(1)	(1)	(1)	(2) $\Sigma = 5$
Parameter 3: water flow.			
In the direction M → J, MD, the existing vegetation, although secondary, influences the flow of the body of water	50 m ahead, on this bank, there are buildings and toilets on this bank, which can contribute to the mass of waste in the water flow that enters the homes when it rains at the head of the stream.	The central channel is getting narrower and narrower due to construction and landfill, as well as the growth of aquatic vegetation.	Here, the presence of "jiraus" was observed. As this area is on the outskirts, this structure is built over the water, which is submerged in the event of rain.
(3)	(0)	(1)	(1) $\Sigma = 5$
Parameter 4: maintenance of the riparian forest			
The riparian forest, already in its secondary stage in the MD, is maintained in the first 50 m from the source.	In the ME, this riparian forest, also secondary, extends to the central channel.	After the drain (Bridge), in the ME, the riparian forest was completely replaced by agricultural and ornamental crops.	In the MD, after draining an initial 15 m, landfilled, and up to 95 m ahead, there is a rise in architectural units, with landfilling of the bed and suppression of this vegetation.
(2)	(1)	(1)	(1) $\Sigma = 5$
Parameter 5: extension of riparian forest			
In the ME, direction M → J, there is a more intense extension, compared to the MD, in the initial 50 m, before the source.	Also in this sense, in MD, the extension decreases sharply to give rise to backyards.	In the 80 m after the drain, this vegetation no longer exists, as it has been replaced by crops and recreational areas.	After the last jirau, 100 m from the drain, the ME has secondary vegetation, with no dwellings, and the same occurs in the MD.
(2)	(0)	(0)	(4) $\Sigma = 7$
Parameter 6: Presence of aquatic plants			
Before the fountain, there is a predominance of marsh Brachiaria (Brachiaria ssp.) and monkey's ear (Cotyledon ssp.).	Under the bridge, in the section from the water flow to the drain, there is a large volume that causes a blockage in this flow.	After the drain, the aquatic plants continue with the same representatives.	After 200 m (100 m before the source and 100 m after the drain), the aquatic vegetation decreases and there is more marginal leafiness.
(1)	(0)	(1)	(4) $\Sigma = 6$
Parameter 7: Type of substrate			
In this parameter, sandy bottoms prevail. In MD, 50 to the source.	In the central channel, there is muddy and leafy material.	In the ME, there is a prevalence of clay material.	After 100 m from the drain, sandy material again predominates at the bottom.
(1)	(1)	(1)	(1) $\Sigma = 4$
$\Sigma = 37$			

Adapted from Callisto *et al.* (2002).

3.3.3. Environmental Integrity Index - IIH

The analysis of the data, in this area, for the HII (10.4), the quality "highly impacted". This is because both A.I. (5.3) and E.C.(5.1) contributed with the same intensity to habitat degradation

4 DISCUSSIONS

In the three areas evaluated using IIH, the vegetation cover was suppressed. However, in A3, the marginal vegetation cover has been replaced by secondary cover, although it does not have the same function as the natural cover, and is contrary to Law 12.651/2012, especially in the so-called riparian zone. Regarding this zone, Silva *et al.* (2022), in their research conducted in the lower Tapajós river basin, Pará, stated that the loss of this zone in water bodies causes a reduction in biodiversity.

From this perspective, Santos *et al.* (2021), in a study conducted in the municipality of Santarém, Pará, in six streams in this municipality, concluded that five of them presented irregularities due to this law, which harms the habitat of the local flora and fauna. Another factor of degradation in the three areas analyzed is the occurrence or non-occurrence of aquatic fauna, as many residents of this municipality have asked the authors of this research if the fish that used to occur in these places are no longer found.

If the habitat has been altered, this could compromise the ichthyofauna. In this line of research, Magalhães *et al.* (2020) conducted a study on the composition of the ichthyofauna in 24 streams in the Xingu River basin. In this research, the authors concluded that modifications to the structures of these water bodies cause a decrease in the diversity of fish, especially those that are more sensitive. This was observed especially in the informal conversations of passers-by, who claim that tucunarés (*Cichla ocellaris* Bloch & Scheider, 1801. Family Cichlidae³) used to occur in Green Lake in the past but no longer do.

In this lake, changes in morphology have occurred from a number of perspectives, including the meander, associated with the narrowing of the extension, an increase in the storage volume and consequently in the reception of water from the

³ Brazilian Biodiversity Information System – BBIS/SiBBR. Retrieved from: [Cichla ocellaris: Tucunaré | SiBBR](#).

Paragominas stream. All caused by land use and occupation. With this approach, Delgado (2022) conducted a study on the environmental state of the Quarenta creek, a component of the Educandos creek micro-basin, in the district of the same name, Manaus, Amazonas, which runs through 15 districts in the city.

The degradation identified by this author causes losses in ecosystem services and there is a need for a review in the context of watershed conservation. In the three areas analyzed, it is taken as evidence for this proposition that the recomposition or replacement of the riparian zone has a portion of endemic vegetation, since the Paragominas stream runs through four neighborhoods: Camboatã, Tião Miranda, Célio Miranda and Promissão.

In A₃ the meandering sinuosity is present. It begins just after Avenida Fausto Fernandes Deputy, in the Tião Miranda neighborhood, although it already has severe anthropogenic impacts such as the construction of concrete bridges and architectural units. When it enters Padre Carvalho street, in the Promissão neighborhood, the meander is already altered for these reasons, all of which modifies the habitat of aquatic flora and fauna and favors the growth of exotic aquatic vegetation.

Along these observational lines, Bentos *et al.* (2021), in research conducted on the Araras stream, in the municipality of São Paulo, concluded that when sediment, branches, mud, erosive processes and changes in land use and occupation are deposited, the habitat changes. In the Paragominas creek, all these reports were evidenced in the three areas analyzed, corroborating the qualifications issued: all are, according to the IIH analysis, "highly impacted".

Therefore, the application of the Habitat Integrity Index (HII) has been applied effectively and efficiently in these types of studies (Bollmann; Edwiges, 2008; Callisto *et al.*, 2002; Gambarotto, 2012; Mendonça; Magnusson; Zuanon, 2005; Nessimiann *et al.*, 2008; Rodrigues *et al.*, 2010; Santos *et al.*, 2017), in creeks because when they are altered, modified and transformed by anthropogenic impacts, the aquatic biota responds in different ways and, in general, the greatest sensitivity of the aquatic fauna as well ichthyofauna in relation to the physical-chemical alterations of the aquatic ecosystems, associated with suppression and/or modification in the riparian forest, especially those located in urban stretches.

5 CONCLUSIONS

The three areas along the most urbanized stretch of the Paragominas creek, in the municipality of the same name, are highly impacted. Particularly A₂, Green Lake, because the transformation of a former open dump has completely de-characterized the aquatic morphophysiological conditions and the provision of ecosystem services is active with restrictions. This can be seen in A₁, which is used little for bathing.

The supply of fish has collapsed; thermal regulation with sparse and sparse riparian vegetation does not comply with the new Forest Code and does not play this role effectively. At A₂, Green Lake, the reception of domestic and rainwater effluents mixes together, causing physical and chemical alterations to the integrity of the habitat. The asphalt and cement paving around the banks of the three areas may be compromising the infiltration and percolation of rainwater, resulting in flooding and waterlogging. In A₃, ME, direction M → J, the establishment of agricultural crops is not recommended because the current width of the Paragominas creek is minimal, and in the event of high rainfall rates, there will be flooding that will wipe out the crops. The recreational backyards observed in these areas are also not possible due to non-compliance and the imminent risk they present during the winter season, and the waste generated tends to be thrown into the water body analyzed, which alters the aquatic habitat.

Finally, it is hoped that the data contained here can help the municipal bodies that manage water resources in Paragominas to plan actions to mitigate, monitor and control the anthropogenic impacts identified here and promote improvements in the environmental conditions of the Paragominas creek, especially during the Amazonian winter, when flooding occurs frequently in these three areas.

ACKNOWLEDGEMENTS

To the State University of Pará, for the doctoral scholarship awarded to the first author. The data contained herein makes up Scenario III of the thesis (Scenario III) being developed in the Graduate Program in Environmental Sciences (GPES/PPGCA) of this higher education institution. To Mr. Ruy Marcos Minto, for the countless donations of the aluminum boat, to Mr. Sandro de Araújo Andrade, a permanent employee of *Campus VI*, for the countless donations of oral and photographic information. To Mr. Railsson Dias Pereira (Topographer). To the Paragominas Municipal Environment

Department (SEMMA) for permission granted, which is generating useful data for the conservation of water resources in this municipality.

REFERENCES

ALLAN, J. D. **Stream ecology**. Structure and function of running waters. California: Textbook, 1995.

ALMEIDA, T. S. *et al.* Impactos antrópicos e efeitos eco evolutivos sobre a Biodiversidade. *In: Ensino da Biologia: uma perspectiva evolutiva*, v. II. Porto Alegre: Instituto de Biociências da UFRGS, 2021.

ARAÚJO, R. M. G. *et al.* Diagnóstico da integridade ambiental de trechos de um creek por meio de protocolo de avaliação rápida – Rio Branco, AC. **Revista Brasileira de Ciências da Amazônia**, v. 9, n.º 4, p. 29-37, 2020.

BENTOS, A. B.; GALLO, A. S.; GUIMARÃES, N. F. Avaliação Rápida de Impactos ambientais em rios: aplicação na microbacia do Ribeirão das Araras. *In: SALES, R. E. S.; SALES, R. S. Educação Ambiental e Cidadania: Pesquisa e Práticas Contemporâneas*, v. 1. Guarujá: Científica Digital, 2021.

BEZARRA, P. C.; SOUZA, J. D. Urbanização de Tabatinga e impactos ambientais: estudo de caso do creek Urumutum. **Revista Geo Amazônia**, v. 9, n.º 17, p. 111-125, 2021.

BOLLMANN, H. B.; EDWIGENS, T. Avaliação da qualidade das águas do rio Belém, Curitiba-PR, com o emprego de indicadores quantitativos e perceptivos. **Engenharia Sanitária e Ambiental**, v. 13, n.º 4, p. 443-452, 2008.

CALLISTO, M. *et al.* Aplicação de um protocolo de avaliação rápida da diversidade de habitats em atividade de ensino e pesquisa (MG-RJ). **Acta Limnológica**, v. 14, n.º 1, p. 01- 08, 2002.

CONCEIÇÃO, M. M. M. A lógica fuzzy no estudo da qualidade da água do rio Uraim Paragominas – PA. **Brazilian Journal of Development**, v. 6, n.º 6, p. 38575-38588, 2020.

CRUZ, M. E. G. *et al.* **Os aningais : um tipo de vegetação “quase extinta nas cidades amazônicas”**. Belém: Embrapa Amazônia Oriental, 2008.

DELGADO, M. B. C. **As trilhas do espaço-tempo na paisagem das seções fluviais inferior-médio do creek do Quarenta: sistema hidrográfico de Educandos**. 2022. Dissertação (Mestrado em Geografia) – Curso de Geografia. Universidade Federal do Amazonas, Manaus, 2022.

DIAS, G. K S.; RUBIM, M. A. L. Qualidade das nascentes de creeks da cidade de Manaus, Amazonas. *In: Francisco, P. R. M. et al. (Org.) Engenharia, Agronomia e Geociência, 2014-2021*. Campina Grande: EPTEC, 2021, cap. VIII, p. 92-106.

EPA. Environmental Protection Agency. **Biological criteria for the protection of aquatic life**. Division of Water Quality Monitoring and Assessment, Columbus, v. I-III, 120 P. Surface Water Section, 1987.

GAMBATOTTO, B. L. **Proposta de índice de Integridade Ambiental aplicado a riachos de mata Atlântica e aplicação de teste de validade com parâmetros da Assembleia de peixes**. Monografia (Bacharelado em Engenharia Ambiental) – Curso de Engenharia Ambiental – Universidade Tecnológica Federal do Paraná, Curitiba, 2012.

HAMID, A. *et al.* Local determinants influencing stream water quality. **Applied Water Science**, v. 10, n.º 24, 2020

HANNAFORD, M. J. *et al.* Training Reduces Observer Variability in Visual - Based Assessments of Stream Habitats. **Journal of the Norte American Benthological Society**, v. 16, n. 4, p. 853-860, 1997.

LUZ, L. M. *et al.* Impactos antropogênicos em bacias urbanas da área central da cidade de Belém-PA. **Revista Geo Amazônia**, v. 03, n.º 06, p. 96-106, 2015.

MAGALHÃES K. X. *et al.* Influência de fatores ambientais na composição taxonômica de peixes de igarapés. **Revista Multidisciplinar de Educação e Meio Ambiente**, v. 1, n.º 2, s/p, 2020.

MENDONÇA, F. O.; MAGNUSSON, W. E.; ZUANON, J. Relationship between habitat Characteristics and fish assemblages in small streams of Central Amazon. **Copéia**, n.º 4, p. 751-764, 2005.

MITCHELL, G. Problems, and fundamentals os sustainable development indicators. **Sustainable Development**, v. 4, n.º 1, p. 1-11, 1996.

NESSIMIANN. J. L. *et al.* Land use, habitat Integrity and aquatic insect assemblages in CENTRAL Amazonian streams. **Hydrobiology**, n.615, p. 117- 131, 2008.

PARÁ. Fundação Amazônia de Ampara a Estudos e Pesquisas. **Estatística municipal**. Belém: FAPESPA, 2023.

PAZOS, A. C. C.; CHAMORRO, F. R. M. Metodología para evaluación de amenaza por flujo detonado por lluvia, en la microcuenca el rollo municipio de San Bernardo, Nariño. **Revista Ingeniería, Investigación y Desarrollo**, v. 21, n. 2, p. 35-46, 2021.

PIMENTEL, D. R. *et al.* Diagnóstico ambiental da vegetação ripária e da microbacia de um riacho urbano amazônico. **Revista Saúde e Meio Ambiente**, v. 12, n.º 02, p. 166-180, 2021.

PRABHU, R.; COLFER, C. J. P.; DUDLEY, R. G. **Guidelines for developing, testing, and selecting criteria and indicators for sustainable forest management**. Toolbox series, n.º 1, Indonésia: CIFOR, 1999.

RODRIGUES, A. S. L.; MALAFAIA, G.; CASTRO, P. T. A. A importância da avaliação do habitat no monitoramento da qualidade dos recursos hídricos: uma revisão. **Revista Saúde e Biologia**, v. 5, n.º 1, p. 26-42, 2010.

RODRIGUES, R. S. *et al.* Análise dos efeitos de um evento extremo de chuva sobre o escoamento superficial em uma pequena bacia hidrográfica rural Amazônica. **Revista Brasileira de Climatologia**, v.26, p. 368-392, 2020.

RODRIGUES, T. E. *et al.* **Caracterização de classificação dos solos do município de Paragominas, estado do Pará**. Belém: EMBRAPA, 2003, Documento 162.

SANTOS, G. P.; OLIVEIRA, L. L.; MORTATI, A. F. Aplicação do índice de integridade do habitat e sua relação com a qualidade da água e com a hidrodinâmica de creeks urbanos amazônicos. *In*; **Simpósio brasileiro de Recursos Hídricos**. 22, 2017. Santa Catarina. Disponível em: [ABRHidro - ANAIS - APLICAÇÃO DO INDICE DE INTEGRIDADE DO HABITAT E SUA RELAÇÃO COM A QUALIDADE DA ÁGUA E COM A HIDRODINÂMICA DE CREEKS URBANOS AMAZONICOS](#).

SANTOS, G. P. *et al.* Efeitos da Integridade ambiental da zona ciliar e sua influência na qualidade da água de creeks urbanos em Santarém - PA, Amazônia, Brasil. **Revista Brasileira de Geografia Física**, v. 14, n.º 7, p. 4035-4055, 2021.

SILVA, J. R. P. *et al.* Efeitos da degradação em zonas ripárias sobre a estrutura da vegetação de palmeiras de Terra Firme na Amazônia. *In*: **Congresso Florestal Brasileiro**, n.º 9, 2022. São Paulo: Artigos. São Paulo: Softaliza, 2022, p. 103-106.

WATRIN, O. S.; ROCHA. A. M. A. Levantamento da vegetação natural e do uso da terra no município de Paragominas (PA) utilizando imagens TM/Landsat. Belém: EMBRAPA-CPATU, 1991. Boletim de Pesquisa, 124.

Cenário III. A urbanização, a qualidade da água sob a visão da integração ambiental quanto a poluição.

ARTIGO 4

Preliminary analysis of water quality in the urban stretch of Paragominas stream, Pará, Brazil

ABSTRACT

The growth of the urban area of Paragominas is causing problems for water resources. This was observed due to the lack of data on the water quality of the Paragominas stream, in the urban stretch. This gap needs to be filled, which is why this research was conducted on this stream and this stretch. The aim was to verify the state of water quality using six parameters (five physical: temperature, electrical conductivity, total dissolved solids, turbidity and hydrogen potential; one chemical, dissolved oxygen) in five areas (A₁, A₂, A₃, A₄, A₅), in the three sections (SI - right bank; SII - central channel; SIII - left bank). The methodology used was investigative with a qualitative approach. Primary data was obtained using electrometric instruments (multi-parameter probe, turbidimeter and thermometer with a probe). The data obtained and analyzed indicated that the water temperature in the five areas had an average value above the annual forecast (± 26 °C/year) for the municipality (29.0 ± 3.3); electrical conductivity had the highest average value in A₃ (390 ± 41.0); TDS, in A₁, had the highest average (256 ± 13.9); turbidity, was more pronounced in A₂ (24.1 ± 15.1); DO, the lowest value occurred in A₅ (0.3 ± 0.6). After applying for the PCA, it was identified that, of the six parameters used, the ones that may be contributing most to the change in water quality are EC and TDS. Based on these observations and the values obtained, the urban stretch of the Paragominas stream is at risk of significant changes leading to pollution and contamination.

Keywords: Permanent Protection Area. Surface Water. Landscaping. Water Pollution. Urbanization.

RESUMO

O crescimento da área urbana de Paragominas, está causando problemas aos recursos hídricos. Isto foi observado devido à falta de dados quanto a qualidade da água do igarapé Paragominas, no trecho urbano. Esta lacuna precisa ser preenchida, por isto, esta pesquisa foi efetuada neste igarapé e neste trecho. O objetivo foi verificar o estado da qualidade da água como uso de seis parâmetros (cinco físicos: temperatura, condutividade elétrica, sólidos totais dissolvidos, turbidez e potencial hidrogeniônico; um químico, oxigênio dissolvido) em cinco áreas (A₁, A₂, A₃, A₄, A₅), nas três seções (SI – margem direita; SII – calha central; SIII - margem esquerda). A metodologia empregada foi a investigativa com abrangência qualiquantitativa. A obtenção de dados primários foi efetuada o uso de instrumentos eletrométricos (sonda multiparâmetros; turbidímetro e termômetro com sonda). Os dados obtidos e analisados indicaram que a temperatura da água nas cinco áreas, apresentou valor médio acima da previsão anual (± 26 °C/ano) para o município (29.0 ± 3.3); a condutividade elétrica apresentou o maior valor de média na A₃ (390 ± 41.0); STD, na A₁, apresentou a maior média (256 ± 13.9); turbidez, foi mais acentuada na A₂ (24.1 ± 15.1); OD, o menor valor ocorreu na A₅ (0.3 ± 0.6). Após a aplicação da ACP, foi

identificado que, dos seis parâmetros utilizados, as que mais podem estar contribuindo para a alteração na qualidade da água são CE e STD. Por estas observações e pelos valores obtidos, o trecho urbano do igarapé Paragominas, está em risco de ter incrementada alterações significativas que conduzam a poluição e, quiçá a contaminação dele.

Palavras-chave: Área de Proteção Permanente. Águas Superficiais. Paisagismo. Poluição Hídrica. Urbanização.

RESUMEN

El crecimiento del área urbana de Paragominas Causa problemas a los recursos hídricos. Esto se observó debido a la falta de datos sobre la calidad del agua del arroyo Paragominas, en la sección urbana. Este vacío necesita ser llenado, por lo que esta investigación se llevó a cabo en esta corriente y en este tramo. El objetivo fue verificar el estado de la calidad del agua utilizando seis parámetros (cinco físicos: temperatura, conductividad eléctrica, sólidos disueltos totales, turbidez y potencial de hidrógeno; un químico, oxígeno disuelto) en cinco áreas (A₁, A₂, A₃, A₄, A₅), en las tres secciones (SI – margen derecha; SII – cuneta central; SIII - margen izquierdo). La metodología utilizada fue investigativa con alcance cualitativo. Los datos primarios se obtuvieron utilizando instrumentos electrométricos (sonda multiparamétrica; turbidómetro y termómetro con sonda). Los datos obtenidos y analizados indicaron que la temperatura del agua en las cinco zonas presentó un valor promedio por encima del pronóstico anual (± 26 °C/año) para el municipio ($29,0 \pm 3,3$); la conductividad eléctrica presentó el valor promedio más alto en A₃ ($390 \pm 41,0$); La ETS, en A₁, tuvo el promedio más alto ($256 \pm 13,9$); la turbidez fue más pronunciada en A₂ ($24,1 \pm 15,1$); OD, el valor más bajo ocurrió en A₅ ($0,3 \pm 0,6$). Tras la aplicación del ACP, se identificó que, de los seis parámetros utilizados, los que más pueden contribuir al cambio en la calidad del agua son la CE y la STD. A partir de estas observaciones y de los valores obtenidos, el tramo urbano del arroyo Paragominas se encuentra en riesgo de presentar cambios significativos que conlleven a la contaminación y, tal vez, a la contaminación de esta.

Palabras clave: Zona de Protección Permanente. Aguas Superficiales. Paisajismo. Contaminación del Agua. Urbanización.

1. INTRODUCTION

The rapid economic and population growth (ROCHA *et al.*, 2023) universal and the migration of this population to urban areas, has raised concerns about the quality of surface water that make up the history of the creation of each of these areas (MURPHY *et al.*, 2023; STROKAL *et al.*, 2021). This quality, especially in streams, is better evaluated in dry periods (MELO; MACHADO, 2024), and its sources are the deposition of solid waste in or on the banks of it (SANTOS *et al.*, 2021).

In Brazil, in Brazilian Amazon, one of the most arduous tasks in water bodies is due to the extension of the hydrographic basin, that is, approximately six million square kilometers (FASSONI-ANDRADE *et al.*, 2023). Another factor is the physicochemical analysis of these waters, as in the case of sediments, because it originates from the erosion of rocks from which they originate and which can be dragged from the Solimoes river or deposited in areas far from where they were generated (BRINGEL, 2024).

Another problem is regarding the measurement of acidity because the geomorphological aspects of the formation of Amazonian municipalities and cities have their own peculiarities, in addition to natural cycles such as rainwater, tidal floods and ebbs (CARDOSO *et al.*, 2020), and the formation of streams. When the hydrogen potential (pH) is measured, the values oscillate between 3.5 and 4.5 when acidic and can reach neutrality when they reach a value equal to 7.0 (SILVA *et al.*, 2013).

Such water bodies can be classified as first or second order, and behave as tributaries of rivers considered small, medium, and large (AMORIM, 2018). However, in the Amazon hydrographic basin, the water classification is difficult, due to the deformity of the Amazonian waters (SILVA; MIRANDA; SANTANA, 2016). In the urban context, streams are practically excluded from the new landscaping that arises from this context when the rigging of urban areas causes changes in their geographical context, such as loss of the permanent protection area, modification of the natural course, both in width and depth (GROBE, 2019).

Another way to characterize the streams in this context is in terms of the socio-environment. One of these examples is the knowledge of three different perspectives: 1) urbanization; 2) environmental; 3) social (FERREIRA; VALLINA, 2015). In addition to these changes, there is also the quality of the water whose physical-chemical components (e.g., presence of sulfides; changes in the Hydrogen potential; electrical conductivity, among others) change with urbanization, and this can occur even in springs that are in areas of permanent preservation, because the growth of the population and the expansion of the urban area already begins to change the points of origin of the streams (SANTOS, 2017; SOUZA-FILHO; BATISTA; ALBUQUERQUE, 2019).

In the study of the relationship between urbanization and streams in urban areas, the damage to the latter lies in the alteration of the soil, from the impermeabilization, whether cementitious and/or asphalt, the vital consequence falls on the surface runoff and the infiltration in the soil that would promote the recharge of the streams, that is,

the terrestrial phase of the hydrological cycle is compromised (TARGA *et al.*, 2012). There is also the use of these water bodies to constitute dams in the rural area, and this is one of the factors that can compromise the flow.

Consequently, changes occur in biogeochemical reactions such as changes in the parameters of dissolved oxygen (DO) and nitrate (NO^{-3}), caused by environmental degradation such as urbanization or inappropriate land use (FIGUEIREDO, 2009). The main channel of this hydrographic basin passes through the urban area, the problem is that when this happens, it becomes a receiving body for urban effluents, as well as solid waste such as plastics, metals, wood, refrigerators, among others.

All this affects the physicochemical and microbiological composition of rivers and streams. In this context, the Paragominas stream is inserted, in the homonymous municipality, but there are no studies and research on the water quality in the stretch of this stream that runs through the urban area, and presents major changes in the natural physical structure, with elevated marginal urbanization, construction of road platforms, among other landscape modifications (SOUSA, 2019).

All the problems reported here and the absence of this type of analysis, justified the relevance of this research in the Paragominas stream, in the urban stretch of the homonymous municipality, whose objective was to verify the water conditions of temperature, electric current, total dissolved solids, turbidity, pH and dissolved oxygen, due to the expansion of the urban area of this municipality in five areas through which this stream crosses. The generation of this data will contribute to a more effective management of the waters of Paragominas and will further improve the environmental quality of this creek that serves as a recreation and nutrition center.

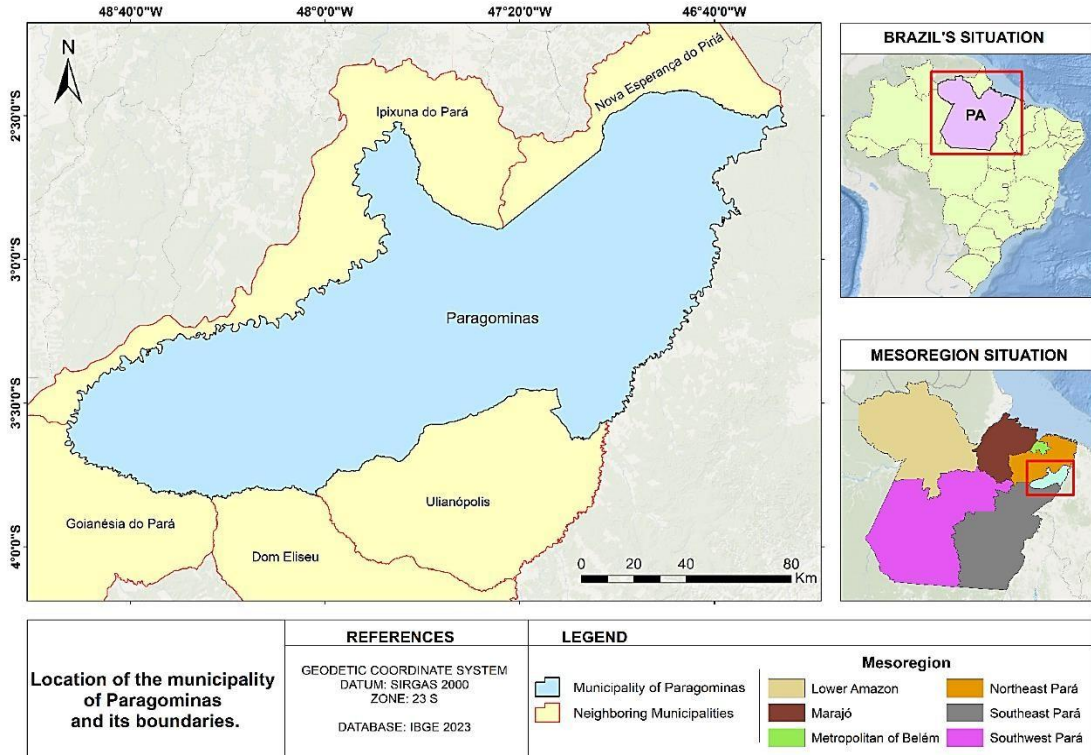
2. MATERIAL AND METHODS

2.1 PHYSIOGRAPHY OF THE MUNICIPALITY

The municipality of Paragominas, in the southeast of Pará, where the research was developed, is located 316 km from the capital, Belém, and has the following geographic coordinates: 223948 E; 9671781 N (Figure 1). Access is made by two highways, one federal (BR – 010), and the other state (PA 125).

The vegetation has two classifications: 1) Mixed open Ombrophilous forest (vines and palm trees); 2) Dense Alluvial Ombrophilous (VASCONCELLOS; BELTRÃO; SILVA, 2016).

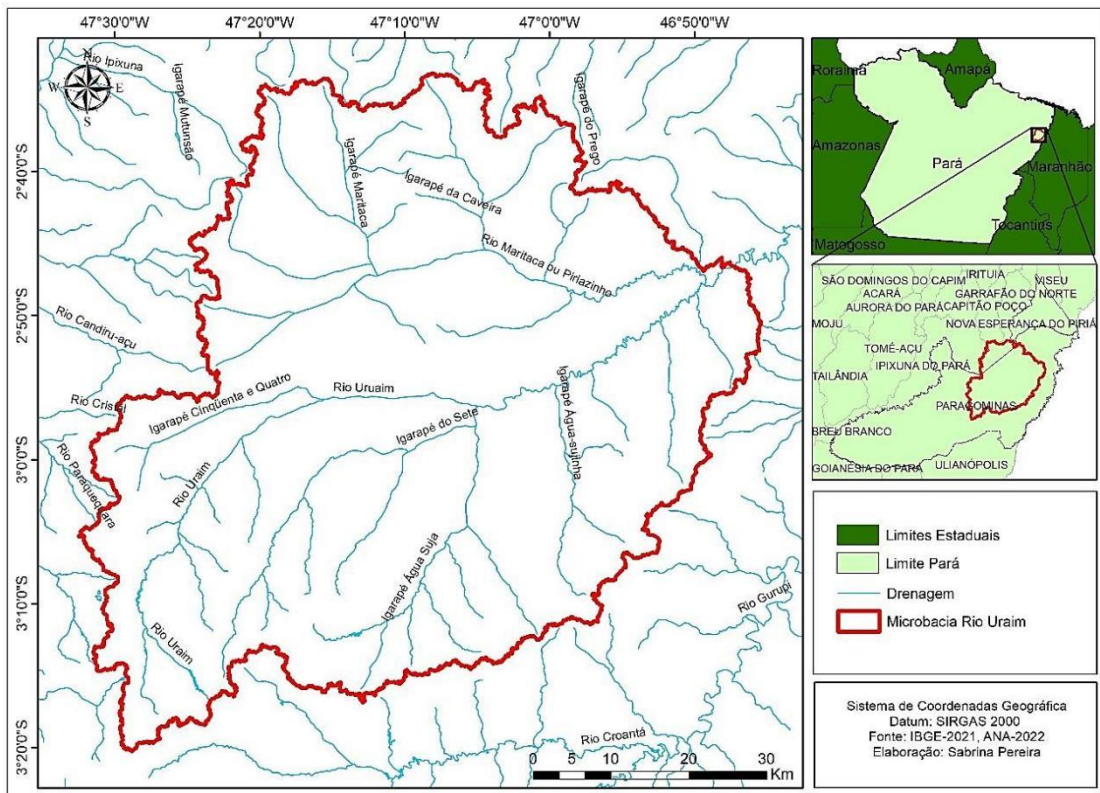
Figure 1. Location map of the municipality of Paragominas. Pará. Brazil.



Prepared by: Melo, E. E. P.

The predominant soil in this municipality is the Yellow Latosol, where the storage of nutrients from forest fires occurred during the colonization process. The climate, based on the Köppen classification, is of the Aw type: tropical rainy, with a well-defined dry period, and the annual average temperature is around 26 °C (RODRIGUES *et al.*, 2003). The micro-hydrographic basin (MCH) of the municipality has as its main water body, the Uraim River (Figure 2), whose drainage network, already measured, has an area equivalent to 4,981 km², and an extension equal to 202 km.

Figure 2. Watershed of the Uraim River and its tributaries. Paragominas, Pará. Brazil.



Prepared by Pereira, S.

It is located at an altitude equal to 255 m, with 1 m in the so-called exutory (CORREA, 2017). Among the tributaries of this river, there are four streams: 1) 54 (VENTURIERI *et al.*, 2005); 2) Seven (GAMA *et al.*, 2007); 3) Paragominas and 4) Parariquera (NEVES *et al.*, 2021). The first two are located in the so-called *rural area* of the municipality of Paragominas. The third has the largest extension in the urban area and does not present hydrological data that help in the water management of the municipality, and the fourth, in the area of bauxite extraction (GONÇALVES, 2007).

As for the third, it is currently a major receiver of domestic effluents in the urban section where it has a flow, either due to relief slope, or due to structured pipes that flow into it, especially in areas where the infrastructure of the neighborhoods does not have basic sanitation such as Camboatã and Tião Mineiro.

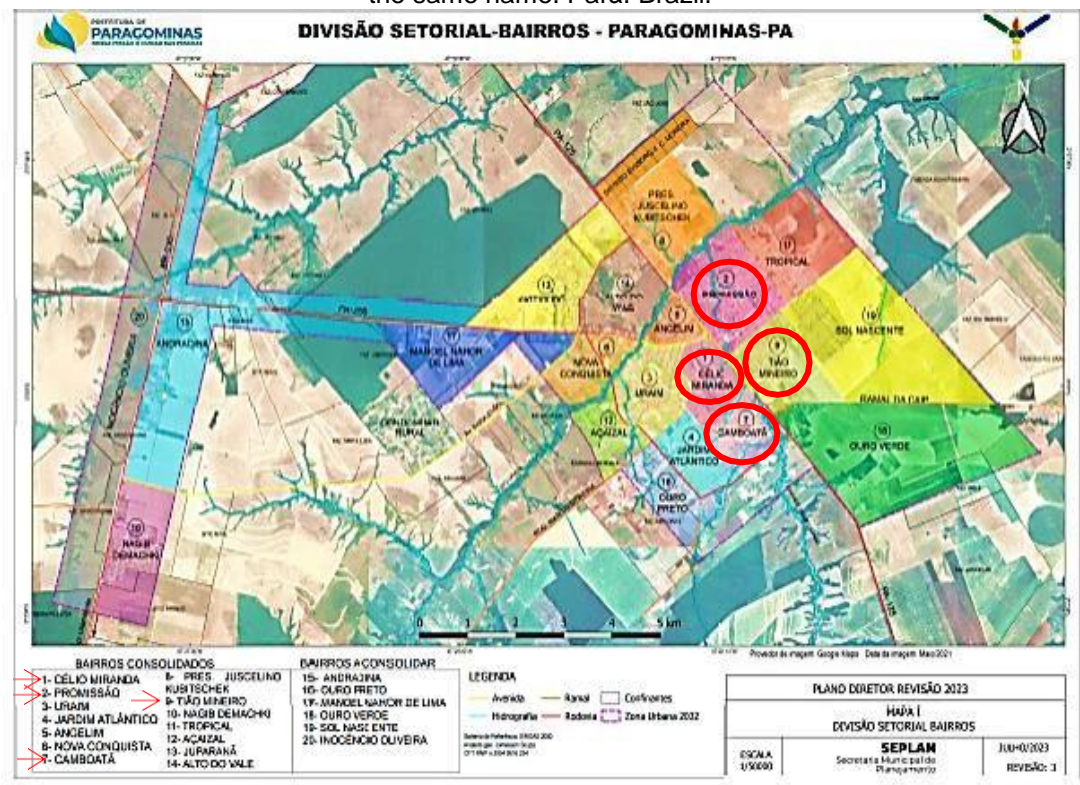
2.2 SELECTED AREAS

The five areas: 1 – Rodovia Constantino Pereira do Sacramento Highway, 850 m from Highway PA 125; 2) Selecta Avenue, 520 m from Rodovia PA 125, both in the

W → E direction; 2 - Confluence of Rua Gregório Santos Araújo street with Rodovia PA 125 Highway – Camboatã neighborhood; 4) Green Lake; 5) Padre Carvalho street. We were selected based on their location in the urban section of the municipality of Paragominas.

The choice was based on their population density due to the growth in demographic density that occurred between 2010, with a population of 97,819 inhabitants (IBGE, 2010) and 2024, with an estimated population of 112,843 inhabitants (IBGE, 2022). In addition, of the 14 neighborhoods that make up the urban area, three of them are bordering the Paragominas stream: Camboatã, which includes the Selecta Residential Complex, Célio Miranda, Tião Mineiro, and Promissão (Figure 3).

Figure 3. Neighborhoods located on the banks of the Paragominas stream, in the municipality of the same name. Pará. Brazil.



Source: PARAGOMINAS, SEPLAM: 2023.

2.3 DATA COLLECTION

2.3.1 PRIMERS: parameters for water quality

The collection took place in the prolonged dry period until July 2023 a November/2024. The six parameters, (five physical; one chemical) were measured in the five areas object of this study, in each of the three predetermined sections (Board 1).

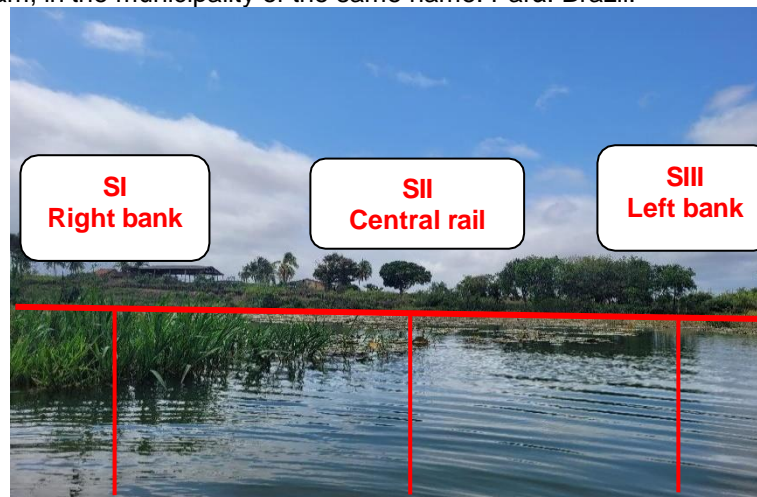
Board1. Electrometric instruments are used to obtain data on the six parameters (five physical, one chemical) measured. Paragominas stream, in the municipality of the same name. Pará. Brazil.

Measured Parameters	Acronyms	Units	Electrometric instrument used	Brand: Model
Physical Parameter				--
Temperature	--	°C	Thermometer with probe	Instrument: TH-1600 ¹
Electrical conductivity	EC	$\mu\text{S}/\text{cm}^{-1}$	Multi Parameter probe	AKSO: SX 836
Total Dissolved Solid	TDS	mg/L		
Hydrogen Potential	Hp	--		
Turbidity	--	mg/L	Monoparâmeter probe	AKROM: KR2000
Chemical Parameter				
Dissolved Oxygen	DO	mg/L	Multi Parameter probe	AKSO: SX 836

¹ Type K, with datalogger. Source: Prepared by the authors

To determine the sections, a marginal extension of 66 m was measured in the W → E direction, then three meters were subtracted on each of the sides, the final value obtained was divided by three and, with this, the three sections were established: I - right margin; II - central gutter; III - left margin (Figure 4).

Figure 4. Identification of the sections adopted for this research. Paragominas stream, in the municipality of the same name. Pará. Brazil.



Source: Prepared by the authors

The data obtained were tabulated (Table 1) according to the norms established by the Brazilian Institute of Geography and Statistics (IBGE, 1993). They were then

compared with the values allowed by the resolution of the National Council for the Environment – CONAMA No. 375 (BRASIL, 2005), and updated by Resolution No. 430 (BRASIL, 2011).

Table 1. Model used to enter the data obtained for the physico-chemical parameters of the five areas analyzed. Paragominas stream, in the municipality of the same name. Pará. Brazil.

Area... - A...	Sections	Geographic Coordinates (23 M – UTM) ¹		Altitude (m)		
	SI	X:	Y:			
	SII	X:	Y:			
	SIII	X:	Y:			
----- Physicochemical Parameters -----						
Analyzed	Acronyms	Units	CONAMA Resolution n.º 357/2005	Values obtained for:		
				SI	SII	SIII
Temperature	T	°C	---			
Electrical conductivity	EC	µS/cm	≤ 100			
Total Dissolved Solid	TDS	mg/L	≤ 500			
Turbidity	--	NTU	10 até 100			
Hydrogen potential	Hp	--	--			
Dissolved Oxygen	DO	mg/L	≥ 5			

¹ Collected with Garmin GPSMAP 65 multi-band handheld. Source: Prepared by the authors

2.3.2 Secondaries

Secondary data were obtained from electronic *links* involved with the research theme and free access such as: Coordination for the Improvement of Higher Education Personnel (CAPES), Elsevier (access via Federal Academic Community - CAFé), Plos One, repositories of federal and state universities. The time limit covered publications made between 2005 and 2024. This cut, which began in 2005, is justified due to the promulgation and publication of CONAMA Resolution No. 357 (BRASIL, 2005) and reformulated by CONAMA Resolution 430 (BRASIL, 2011).

However, the priority for more recent information remained, with publications made in the last five years (2020-2024). To better support the contextualization of this research, so-called pioneering literature was used (ESTEVEZ, 1998; IBGE, 1993; NUCCI, 1999; RODRIGUES *et al.*, 2003), whose academic contents are indispensable for the theme of this research.

2.5 HYDRICAL BODY CLASSIFICATION

As there is a lack of previous studies regarding the classification for the Paragominas stream, the classification contained in the CONAMA resolution (BRASIL, 2005), Section I, On Fresh Waters, item III, items a, b, c, d, e, was used. In relation to items c and the uses of these classifications were associated with what was proven during field visits at certain points of this water body.

2.5 STATISTICAL ANALYSIS OF THE DATA

The data obtained were statistically analyzed with the application of the BioEstat 5.0 PAST 4.0 software, with the use of Descriptive Statistics, linear regression test (p value), and Principal Component Analysis, to identify in which of the three sections analyzed, the physicochemical parameters that contributed to changes in water quality.

3. RESULTS

3.1 PHISICOCHEMICAL PARAMETERS

3.1.1 Area 1 – Constantino Pereira do Nascimento Highway

The data obtained indicated that the mean values for the five physical parameters and one chemical parameter (Table 2) measured are within the limits established by CONAMA Resolution No. 357 (BRASIL, 2005).

Table 2. Average values for physico-chemical standards in A1, in the three sections measured. Paragominas stream, in the municipality of the same name. Pará. Brazil.

Area 1 – A1	Sections		Geographic Coordinates (23 M – UTM) ¹		Altitude (m)	
	SI	SII	X:239926	Y: 9667051	75	75
	SII	SIII	X: 239956	Y: 9667003	75	71
	SIII		X: 240020	Y: 9667006	71	
Physicochemical Parameters -----						
Analyzed	Acronyms	Units	CONAMA Resolution n.º 357/2005	Values obtained for:		
				SI	SII	SIII
Water temperature	T	°C	---	34.4	30.0	32.1
Electrical conductivity	EC	µS/cm	≤ 100	329.3	333.0	344.6
Total Dissolved Solids	TDS	mg/L	≤ 500	245.9	251.2	272.2
Turbidez	--	UNT	10 até 100	14.9	15.0	14.4
Hydrogen potential	Hp	--	--	5.6	5.6	4.9
Dissolved Oxygen	DO	mg/L	≥ 5	2.5	0.8	2.8

Source: Prepared by the authors

3.1.2 Area 2 – Selecta Avenue

The analysis of the data obtained indicated that, in this area, the average values for the pH in the three sections analyzed (Table 3) are in dissonance with the values identified for the Amazonian streams: 4.4 - 5.3, although it is not normalized in CONAMA resolution 357 (BRASIL, 2005).

Table 3. Average values for physico-chemical standards in A2, in the three sections measured. Paragominas stream, in the municipality of the same name. Pará. Brazil

Area 2 – A ₂	Sections	Geographic Coordinates (23 M – UTM) ¹		Altitude (m)		
	SI	X:239601	Y:9667455	79.0		
	SII	X: 239589	Y: 9667398	82.0		
	SIII	X: 239577	Y: 9667411	88.0		
----- Physicochemical Parameters -----						
Analyzed	Acronyms	Units	CONAMA	Values obtained for:		
			Resolution n.º 357/2005	SI	SII	SIII
Water temperature	T	°C	---	31.3	31.5	35.1
Electrical conductivity	EC	µS/cm	≤ 100	308.7	333.0	349.0
Total Dissolved Solids	TDS	mg/L	≤ 500	221.7	257.3	267.7
Turbidez	--	NTU	10 até 100	15.7	15.0	41.5
Hydrogen potential	Hp	--	--	6.3	6.2	6.0
Dissolved Oxygen	DO	mg/L	≥ 5	1.4	2.4	3.0

Source: Prepared by the authors.

3.1.3. Área 3 confluence of Rua Gregório Santos Araújo with Rodovia PA 125 Highway – Camboatã neighborhood

The data obtained and analyzed in this area indicated that the mean values for the pH in section I (Table 4) followed the increase in the mean values for the Amazon streams.

Table 4. Average values for physico-chemical standards in A3, in the three sections measured. Paragominas stream, in the municipality of the same name. Pará. Brazil.

Area 3 – A ₃	Sections	Geographic Coordinates (23 M – UTM) ¹		Altitude (m)		
	SI	X:239373	Y:9667941	77.0		
	SII	X: 239358	Y: 9667931	76.0		
	SIII	X: 239341	Y: 9667917	76.0		
----- Physicochemical Parameters -----						
Analyzed	Acronyms	Units	CONAMA	Values obtained for:		
			Resolution n.º 357/2005	SI	SII	SIII
Water temperature	T	°C	---	31.4	30.5	32.5
Electrical conductivity	EC	µS/cm	≤ 100	389.9	349.0	431.0
Total Dissolved Solids	TDS	mg/L	≤ 500	221.7	257.3	229.6
Turbidez	--	NTU	10 até 100	21.0	25.9	20.2
Hydrogen potential	Hp	--	--	6.3	5.7	5.2

Dissolved Oxygen	DO	mg/L	≥ 5	1.7	2.0	1.3
------------------	----	------	-----	-----	-----	-----

Source: Prepared by the authors

3.1.4 Area 4 – A4. Green Lake.

On the A₄, due to the extension in the M → J direction, it became necessary to widen sections up to 100 m. The data obtained and analyzed for this area showed an upward trend, as occurred in A₁, A₂ and A₃. The mean values for the RE (Table 5) showed the second lowest mean value (0.9 ± 0.1), since the first occurred at A₅ (0.3 ± 0.6).

Table 5. Values for the averages of the physico-chemical parameters in A4. in the three measurements. Paragominas stream, in the municipality of the same name. Pará. Brazil

Área 4 – A ₄	Sections	Geographic Coordinates (23 M – UTM) ¹		Altitude (m)		
	SI	X:239373	Y: 6967941	77.0		
SII	X: 239358	Y: 96679311	79.5			
SIII	X: 239365	Y: 9668003	78.0			
-----Physicochemical Parameters -----						
Analyzed	Acronyms	Units	CONAMA Resolution n.º357/2005	Values obtained for:		
Water temperature	T	°C	---	SI	SII	SIII
Electrical conductivity	EC	µS/cm	≤ 100	38.9	39.6	34.8
Total Dissolved Solids	TDS	mg/L	≤ 500	361.0	354.0	356.0
Turbidez	--	NTU	10 até 100	246	252	256
Hydrogen potential	Hp	--	--	15.3	13.8	14.4
Dissolved Oxygen	DO	mg/L	≥ 5	5.7	5.3	5.4
				1.1	0.8	0.9

Source: Prepared by the authors

3.1.5 Área 5 – A5 Padre Carvalho Street

The data obtained and analyzed for the physicochemical parameters for this area indicated that the average value for the concentration of DO (1.2 mg/l) was within the standards established (< 5 mg/L) by CONAMA Resolution 357 (BRASIL, 2005). It was also observed that the average value for turbidity (Table 6).

Table 6. Average values for physicochemical standards in A5, in the three sections measured. Paragominas stream, in the municipality of the same name. Pará. Brazil.

Area 5 – A ₅	Sections	Geographic coordinates (23 M – UTM) ¹		Altitude (m)		
	SI	X:--	Y: --	--		
SII	X: 238481	Y = 9670497	70.8			
SIII	X: --	Y: --	--			
----- Physicochemical Parameters -----						
Analyzed	Acronyms	Units	CONAMA Resolution	Values obtained for:		
	s			SI	SII	SIII

				n.º357/2005		
Water temperature	T	°C	---	--	32.2	--
Electrical conductivity	EC	µS/cm	≤ 100	--	440.0	--
Total Dissolved Solids	TDS	mg/L	≤ 500	--	333.2	--
Turbidez	--	NTU	10 até 100	--	16.9	--
Hydrogen potential	Hp	--	--	--	6.8	--
Dissolved Oxygen	DO	mg/L	≥ 5	--	1.2	--

Source: Prepared by the authors

4 DISCUSSION

4.1 TEMPERATURE

In the Amazon, the waters of the streams vary according to the location of these water bodies and the relationship between the ambient temperature and the water, which has already been proven in a pioneering study conducted by Esteves (1998). In addition to this fact, there is the occurrence of climate change that was reflected in the measurements conducted, as observed in A₄ (37.8 ± 2.6) and A₅ (10.7 ± 18.6). In A₄, Green Lake, the expansion of the waterbed allows greater absorption of radiance (Table 7).

Table 7. Mean values for the trend of temperature variation in the five areas analyzed. Paragominas stream, in the municipality of the same name. Pará. Brazil.

Measured areas	SI	SII	SIII	\bar{x}	\pm	σ
A1	34.4	30.0	32.1	32.2	\pm	2.2
A2	31.3	31.5	35.1	32.6	\pm	2.1
A3	31.4	30.5	32.5	31.5	\pm	1.0
A4	38.9	39.6	34.8	37.8	\pm	2.6
A5	0.0	32.2	0.0	10.7	\pm	18.6

Source: Prepared by the authors

The tendency for temperature variation in streams, where there was implementation of a road axis, such as on the A₁, Constantino Pereira do Sacramento Highway, in general, is to rise. In the state of Amazonas, Manaus, in the municipality of Iranduba, Wachhols *et al.* (2020), analyzed the interference of the duplication of Highway AM - 070, on water quality and concluded that the water temperature rose (29.2 ± 1.8 °C), due to the extension of the exposed soil, asphalt waterproofing and intense solar radiation on the water mirror.

For A_5 , the low trend in the mean values found in the Sao Paulo Sao Paulo is associated with the marginal and aquatic vegetation cover, in addition to the distance from the architectural units erected there, both in SI (Figure 5a) and SIII (Figure 5b), either before or after (Figure 5c) the concrete bridge.

Figure 5 - a) Vegetation in SI - right bank; b) SII - left bank; c) aquatic vegetation, after the bridge. Paragominas stream, in the municipality of the same name. Pará. Brazil.



Source: Source: Prepared by the authors

In A_5 (10.7 ± 18.6), there was the presence of a greater quantity of arboreal and aquatic vegetation, which did not occur in A_1 , which justifies the values found for this parameter. Reading this fact, Lages *et al.* (2022), carried out, in the city of Manaus, Amazonas, an analysis of the upward trend ou não da temperatura em area with vegetation cover and with little insertion with insertion of industrial waste, and concluded that, in places with these two perspectives, the trend of variation in temperature is practically nil.

The locality factor was proven in the research conducted by Bezerra, Cândido and Monteiro (2007), in the city of Manaus, Amazonas, in two streams, in pasture areas. They concluded that in these types of areas, there was a tendency for temperature variation between 26.5°C and 28.9°C . When the oscillations are increasing and the temperature remains high, and this can interfere with DO concentrations, it slows down chemical reactions in the water and there is insufficient bioavailability for aerobic organisms such as fish. This fact was the object of research conducted in Recife, Pernambuco in the Navio stream (Souza *et al.* (2021).

4.2 ELECTRICAL CONDUCTIVITY

For this parameter, the mean values found for electrical conductivity in the five areas analyzed, it was observed that in four of them, A₁ to A₄, (Table 8) there was a positive oscillation (330.2 ± 20.3 and 390.0 ± 41.0). The latter occurred on the A₄. In A₅, the average value (146.7 ± 254.0), decreased significantly ($\approx 200\%$).

Table 8. Average electrical conductivity values for the five areas analyzed. Paragominas stream, in the municipality of the same name. Pará. Brazil.

Measured areas	SI	SII	SIII	\bar{x}	\pm	σ
A1	329.3	333.1	344.6	335.7	\pm	8.0
A2	308.7	333.0	349.0	330.2	\pm	20.3
A3	389.9	349.0	431.0	390.0	\pm	41.0
A4	361.0	354.0	356.0	357.0	\pm	3.6
A5	0.0	440.0	0.0	146.7	\pm	254.0

Source: Prepared by the authors

Among the numerous reasons for this, it is possible to use the one related to the type of soil in which the analyzed stream has its water flow, because Yellow Latosols, where there is the water flow of the Paragominas stream, are soils rich in soluble minerals that interfere in this parameter. As fertilizers and herbicides are composed of mineral salts with potassium (K) and potassium (K) and magnesium (Mg), this can be related to the place of the source of the Paragominas stream: the rural area.

As the water flow is continuous and has its source in the rural area, this can justify the values found in the urban section, as long as the solubility has not been effective or has been partially so. This statement is based on the research conducted by Souza *et al.* (2020), at the experimental farm of the Federal University of Espírito Santo, the researchers concluded that potassium is one of the stimulating factors for the elevation of EC.

Another contributing factor to this fact is the discharge of pollutants such as domestic effluents because it was observed that from the A₂, Avenida Selecta (Figure 6a), there are culverts (6b) that promote the discharge of these liquids into the Paragominas stream (6c), and this induces the proliferation of marginal aquatic vegetation.

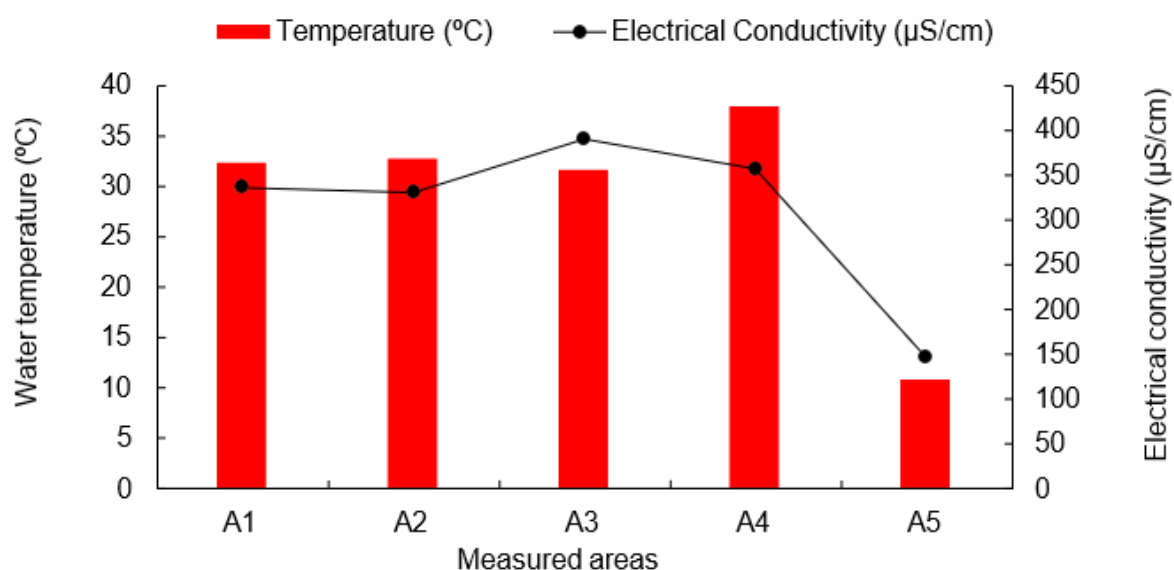
Figure 6. a) culvert through which part of the effluent flows into the Paragominas stream, right bank, direction W → E; b) left bank culvert, direction M → J, in lateral view; c) the same culvert in lateral-frontal view.



Source: Prepared by the authors

Like Green Lake (A₄), it has a greater number of culverts (16). Undoubtedly, this influences the temperature in the EC (Figure 7), as there was a tendency for this physical parameter to increase in this area ($p > 0.018$). As this area is largely urbanized, we follow the report contained in the research carried out by Santos and Ferreira (2014), in the igarapés, Bolivia and Barro Branco, in the Tarumã-Açu river basin, Amazonas, and concluded that the EC, in the urban areas of these igarapés, increased, due to anthropic impacts such as urbanization and generation and deposition of effluents in these surface waters.

Figure 7. Average values for temperature and electrical conductivity in the five areas analyzed in the urban stretch. Paragominas stream, in the municipality of Paragominas, Pará. Brazil



Source: Prepared by the authors

On the A₅, where the presence of utility holes is minimal (only one, on the right bank) which, according to residents, comes from a hospital. This relationship has already been researched by the Environmental Company of the State of São Paulo ((Microsoft Word - Disserta\347\343o Final.doc)). In this research, it was found that for every 1°C of temperature rise, there will be an increase of 2% in the EC. But the reasons that can cause changes in the EC are not only the tendency for variations in the temperature parameter.

In *the in-situ* research conducted by Lima *et al.* (2021), in the laboratory about sewage treatment, based on a relationship between EC and TDS, and concluded that the decrease in the former occurs as a function of the sedimentation that occurs in surface waters. In the study conducted in Manaus, Amazonas, in the hydrographic basin of the Educandos stream, Lages *et al.* (2022), analyzed three physical parameters, including conductivity (EC), and concluded that it changes due to the electrolytes released into the surface waters of this stream.

Such electrolytes are present in untreated domestic effluents, as observed in the study conducted by Barretto, Nour and Domingues (2017), no *campus* da Faculty of Agricultural Engineering of Campinas, and this fact occurs in the areas analyzed in Paragominas.

4.3 TOTAL DISSOLVED SOLIDS – TDS

In the case of TDS, in all five areas analyzed, the values for this parameter ranged between 111.1 and 251.3. In A₅, the lowest value for the meaning of this parameter was obtained. In A₁, this value was the highest (Table 9). In A₂ and A₃, the mean values showed statistically significant differences (> 2).

Table 9. Mean values for Total Dissolved Solids (TDS) in the five areas analyzed. Paragominas stream, in the municipality of the same name. Pará. Brazil.

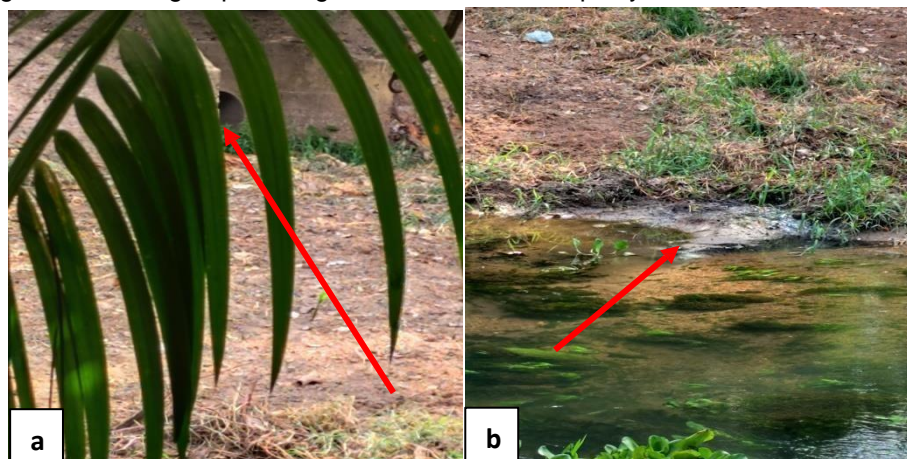
Measured areas	SI	SII	SIII	\bar{x}	\pm	σ
A1	245.9	251.2	272.2	256.4	\pm	13.9
A2	221.7	257.3	267.7	248.9	\pm	24.1
A3	221.7	257.3	229.6	236.2	\pm	18.7
A4	246.0	252.0	256.0	251.3	\pm	5.0
A5	0	333.2	0	111.1	\pm	192.4

Source: Prepared by the authors

Table 8 shows that in A₅, the average value was the lowest. This indicates that, in this area, there is still no effective reception of domestic effluents or the presence of

so-called solid waste, although there is already a culvert (Figure 8a) that is already generating an accumulation of organic matter (Figure 8b) on the right bank, in the direction of M → J. According to residents of the area, it comes from a hospital in the Promissão neighborhood.

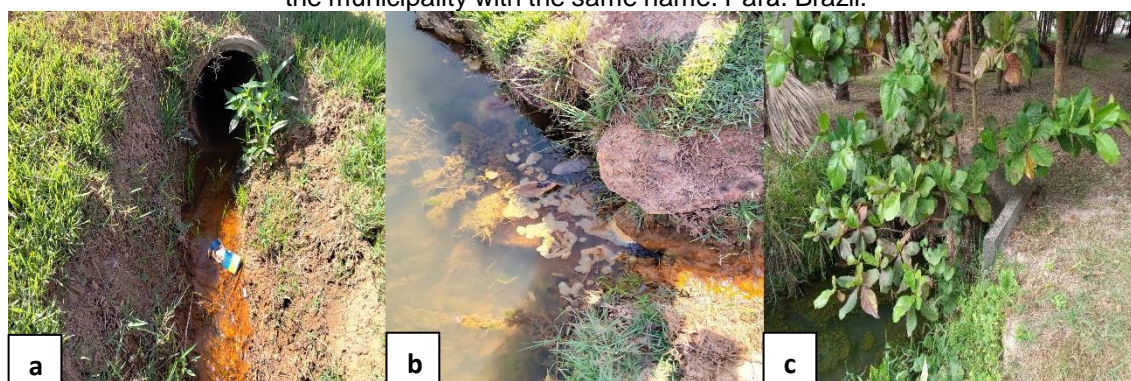
Figure 8. a) culvert raised 3 m from the right bank; b) early-stage accumulation of decomposing organic matter. Igarapé Paragominas, in the municipality of the same name. Pará. Brazil.



Source: Prepared by the authors

This statement is based on the research conducted by Silva, Souza, and da Silva (2024), in the Chico Reis stream, municipality of Rorainópolis, Roraima. These authors concluded that the increase in TDS concentrations is associated with the dumping of domestic effluents and municipal waste. As for the construction of culverts, in general, there is the construction of the so-called "hollow curbs" (Figure 9a), in addition to the accumulation of organic matter after the culvert (Figure 9b), there are still large accumulations of vegetation, as seen in A₄ (Figure 9c).

Figure 9. a) Culvert draining upstream of Green Lake; b) coagulation of organic matter on the shore of Green Lake; c) growth of vegetation at the outlet of the culvert in Green Lake. Paragominas stream. in the municipality with the same name. Pará. Brazil.



Source: Prepared by the authors

4.4 TURBIDITY

It was observed that in the five areas analyzed, turbidity has the highest mean value in A₂ (24.1 ± 15.1), and the lowest in A₅ (Table 10). It is observed that the latter is below the minimum limit (10) established by CONAMA Resolution 357 (BRASIL, 2005).

Table 10 - Average turbidity values for the five areas analyzed. Paragominas stream, in the municipality of the same name. Pará. Brazil.

Measured areas	SI	SII	SIII	\bar{x}	\pm	σ
A1	14.9	15.0	14.4	14.8	\pm	0.3
A2	15.7	15.0	41.5	24.1	\pm	15.1
A3	21.0	25.0	14.7	20.2	\pm	5.2
A4	15.3	13.8	14.4	14.5	\pm	0.8
A5	0	6.8	0	2.3	\pm	3.9

Source: Prepared by the authors

This reduction is explained by the excess vegetation found in this area, whose vernacular name is *Brachiaria do brejo* (*Brachiaria arrecta* (Hack. ex T. Durand & Schinz) Morrone & Zuloaga. Poaceae Family⁴) which, according to information obtained from residents, is extracted, and sold to cattle breeders. Another of great frequency, according to the residents of the analyzed areas, is the water hyacinth, also called by them, as monkey's ear, whose scientific name is *Eichhornia crassipes*, (Mart.) Solms. Pontederiaceae Family (Silveira, 2020).

Another study on turbidity change was conducted by Santos *et al.* (2021), in the municipality of Santarém, Pará, in six urban streams. The researchers concluded that the areas where the population density increase, and basic sanitation is deficient or absent, the volumes of untreated sewage are the cause of the increase in this physical parameter. This corroborates the data obtained in A₂ and A₃.

4.5 HYDROGEN POTENTIAL

Regarding pH, the analysis of the data indicated that plant protection is one of the factors that maintains acidity (2.3 ± 3.9), as occurred in A₅ (Table 11). Another factor is the urbanization process, which in this area is low, both due to the number of residences and the discharge of effluents.

⁴ SiBBr, undated.

Table 11. Average pH values for the five areas analyzed. Paragominas stream, in the municipality of the same name. Pará. Brazil.

Measured areas	SI	SII	SIII	\bar{x}	\pm	σ
A1	5.6	5.6	4.9	5.4	\pm	0.4
A2	6.3	6.2	6.0	6.2	\pm	0.2
A3	6.3	5.7	5.2	5.7	\pm	0.6
A4	5.7	5.3	5.4	5.5	\pm	0.2
A5	0.0	6.8	0.0	2.3	\pm	3.9

Source: Prepared by the authors

Regarding the view of vegetation, Santos, and Ferreira (2014), conducted research in three streams: Barro Branco, Acará and Bolivia, from the Adolpho Ducke Forest Reserve, the values obtained for the pH, between 4.5 and 4.7, indicated that the maintenance of vegetation and little urbanization can maintain the acidity of the water. It can be seen, in table 10, that the evolution of the urban area of the municipality, although the origin is inter-forestry. However, as the urban area expands, there is a loss and alteration of the pH.

Table 11 shows that in A₂, the pH is close to null. This observation was proven from the study carried out by dos Anjos (2022) in 52 streams in the city of Manaus, Pará, whose genesis presents two explanations: 1) canopy spacing by suppression of riparian forest; 2) deposition of allochthonous material on the banks of the streams, causing brownness of acidity, with a tendency to nullity. Such explanations justify what occurred in the pH measurement in areas A₁, A₂, A₃, and A₄.

4.6 DISSOLVED OXYGEN – DO

The values of the averages obtained for this parameter in the five areas measured indicated that in A₄ and A₅ the average concentrations are extremely low (Table 12), and this reflects on the functionality of the aquatic ecosystem and may decline a proliferation of anaerobic bacteria.

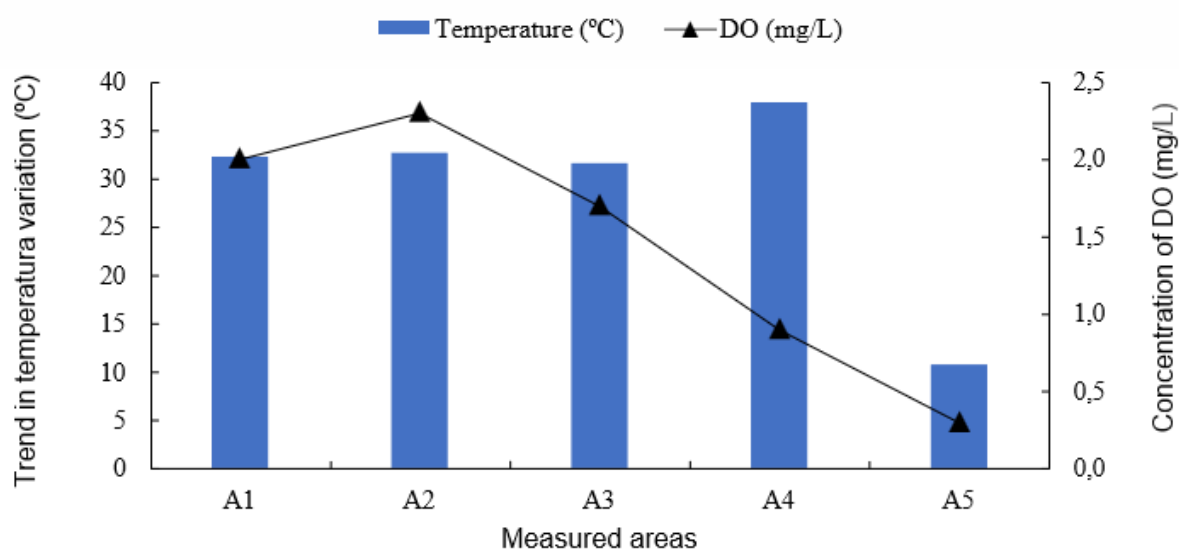
Table 12 - Average values for DO, in the five areas analyzed. Paragominas stream, in municipality of the same name. Pará. Brazil.

Measured areas	SI	SII	SIII	\bar{x}	\pm	σ
A1	2.5	0.8	2.8	2.0	\pm	1.1
A2	3.2	2.4	1.4	2.3	\pm	0.9
A3	1.0	2.0	2.0	1.7	\pm	0.6
A4	0.9	0.8	1.0	0.9	\pm	0.1
A5	0	1.0	0	0.3	\pm	0.6

Source: Prepared by the authors

The values found are responses to inadequate land uses for pastures, such as the formation of scoops and pastures, and the input of nutrients, which caused an increase in the biogeochemical process in this aquatic system as occurred in A₁, and this resulted in a decrease in the DO (Figure 10) and confirmed by the linear regression test ($p = 0.008$).

Figure 10 - Trends of rising temperature and decreasing concentration of DO. Paragominas stream. municipality of the same name. Pará. Brazil



Source: Prepared by the authors

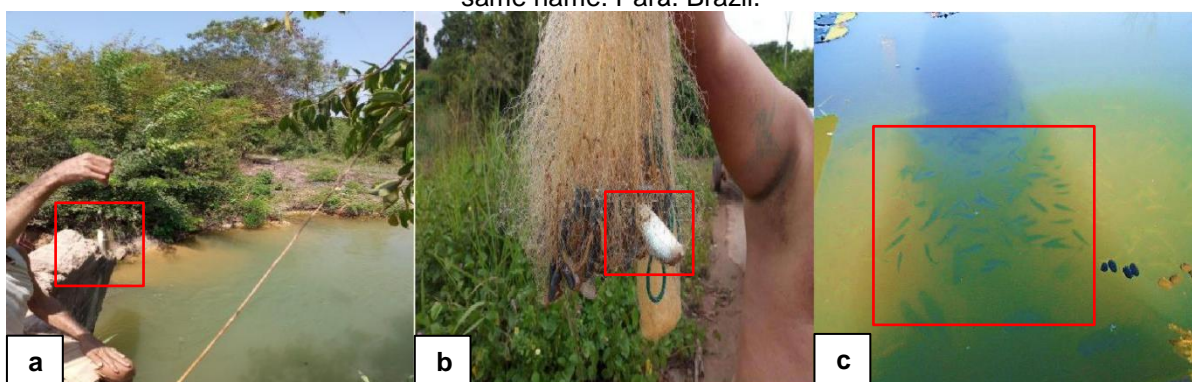
These aspects were evidenced in two studies carried out in the state of Pará: 1) Silva *et al.* (2005), in research carried out on streams 54 and 7, both tributaries of the Uraim river, such as the Paragominas stream; 2) Silva, P., and Silva, M. (2020) in the municipality of Uruará. In both, the authors concluded that the low concentrations of DO were caused by the use and occupation of the soil and the biogeochemical responses of the aquatic systems analyzed. This justifies what happened on the Paragominas stream, especially on the A₁, because, before, the area was occupied by farms and sawmills.

The trends of temperature variations interfere with DO concentrations, and this affects survival conditions due to the bioavailability of this gas to aquatic fauna, which can induce biodiversity loss. Corroborating this statement, the study conducted in lakes in the municipality of Itacoatiara, Manaus, Amazonas, by Silva (2011), proved that low

concentrations of this gaseous compound (2 to 5 mg/L) are tolerable by the ichthyofauna.

When analyzing the concentrations of this gas in A₁ and A₂, passers-by and visitors to these areas reported that there was an abundance of fish in both, fished with improvised rods (Figure 11a) or cast nets (Figure 11b) before paving and urbanization. However, today, this has become a rarity, and with small sizes (Figure 11c).

Figure 11. Fish caught after waiting almost three hours. Paragominas stream, in the municipality of the same name. Pará. Brazil.



Source: Prepared by the authors

This is related to the large accumulation of undecomposed organic matter (OM), since for this to happen, the bioavailability of this gas must occur, which will increase the nutritional bioavailability of the fish. Another problem that this generates was reported by Professor Dr. Roque Passos Piveli, from the University of São Paulo (Microsoft Word - Fascículo 10 - Oxigênio Dissolvido e Matéria Orgânica.doc), such as the retraction of bacterial activity regarding the decomposition of OM, which interferes with the photosynthetic rate of algae. According to this researcher, this occurs in polluted and eutrophic waters.

This description is in line with the research conducted in the streams of the Bolivia Basin, Manaus, Amazonas, Souza *et al.* (2007). In the diagnosis of the water quality of this stream, researchers concluded that water pollution is a factor in the decrease in the supply of DO, which interferes in the decomposition of OM and, consequently, in the bioavailability of this gas for aquatic aerobic organisms and low rate of available food.

5 STATISTICAL ANALYSES

5.1 PRINCIPAL COMPONENT ANALYSIS

For a more careful analysis of the data obtained regarding the six water quality parameters obtained in the five areas analyzed, this analysis was applied, and it was found that CP1 and CP2 represent 99% of the data analyzed (Table 13).

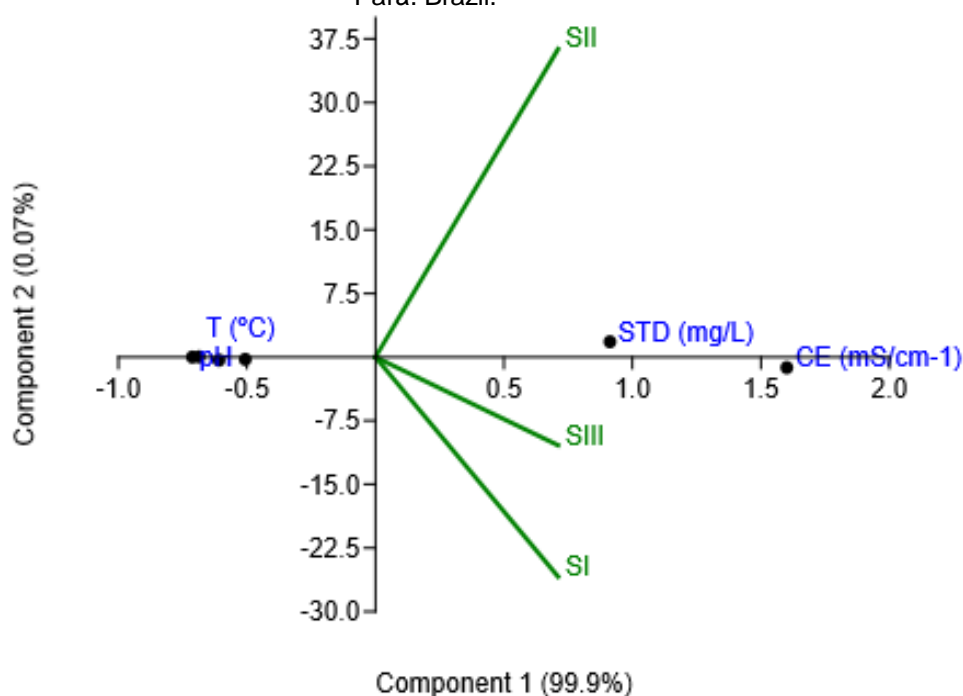
Table 13. Variance obtained when applying the PCA. Paragominas stream, in the municipality of the same name. Pará. Brazil.

PC	Eigenvalue	% variance
1	2.99773	99.924
2	0.00216696	0.072232
3	0.000100373	0.0033458

Source: Prepared by the authors

After obtaining this information and analyzing the horizontal and vertical ordering of the six parameters measured in the three sections, it was possible to identify that the physical parameters TDS (score = 0.8) and CE (score = 1.6) are determinant to indicate changes in water quality in each of them, with more emphasis on SI – central trough, although with less emphasis, also on SII – left bank and right bank (Figure 12).

Figure 12 - Principal Component Analysis of the six water quality parameters in the three sections of the five areas studied. Paragominas stream, in the municipality of the same name. Pará. Brazil.



Source: Prepared by the authors

With this, it is verified that care should be increased with the Paragominas stream. Such precautions are related to pollution by industrial domestic effluents, solid waste deposited in it, in addition to the uplift of architectural units and pavements

that generate the so-called heat islands. In this sense, the research conducted by Nucci (1999), Silva *et al.* 2024, already indicated that adequate urban planning regarding land use and occupation is one of the factors that contribute to adequate environmental quality, especially the maintenance of the quality of urban surface waters.

5 CONCLUSION

In the five areas analyzed, it was found that the occurrence of the urbanization process has been occurring in adequate planning, since the five physical parameters, and one chemical, analyzed indicated that A₁ presents less change in two DO parameters, and Water temperature, indicating that there is a pollutant load entering this area. On A₂, all sections are targeted by anthropogenic impacts, although these two areas are recreational for the low-tent community, as a supplier of food such as fish.

In A₃ and A₄, where urbanization is already present and there is a higher population density, the parameters varied, especially EC and STD, foreshadowing the high frequency of domestic effluent, which compromises water quality, both in terms of recreation and food supply. A₄, now called "Green Lake", urgently needs water quality monitoring and control plan because there are too many culverts draining effluent into it.

In A₅, the average values of the parameters improve significantly when compared to the other areas. However, the construction of recreational backyards, and revolving yards for bathing and domestic use is growing. The "backyards" in this area, at the end of three small streets, are filled with piçarra, this allochthonous material, due to the slope of the soil, enters the Paragominas stream, both by the action of the wind and surface runoff. In addition, a culvert is already implemented and in full operation, which flows the effluents directly into the stream, however, there are no studies regarding their biochemical classification. The residents' statement is that it comes from a hospital.

Therefore, the current condition of the surface waters of the Paragominas Creeks, in the urban section, is in an evolutionary stage for pollution and future contamination, especially in the analyzed section. It is worth mentioning that the physicochemical parameters used here allow such a statement, although they are still

within the values established by CONAMA resolution 357/2005. But a study based on resolution 430/2011, regarding the discharge of effluents, should be conducted as soon as possible to measure the self-purification capacity of this water body.

It is hoped that the data generated here can serve as a basis for municipal public bodies to draw up actions to mitigate and even prevent progress in pollution and contamination, since it is a right-bank tributary of the Uraim River.

ACKNOWLEDGEMENTS

To the State University of Pará for the doctoral scholarship awarded to the first author. The data contained herein is part of the thesis being developed in the Graduate Program in Environmental Sciences (PPGCA) at this higher education institution. To Mr. Ruy Marcos Minto, for the numerous donations of the aluminum boat. To the Paragominas Municipal Department of the Environment (SEMMA) for permission to be granted and allowing the generation of useful data for the conservation of water resources.

REFERENCES

- AMORIM, J. E. L. Característica geoambientais da bacia hidrográfica do Igarapé Água Boa do Intento, Boa Vista, Roraima. **GEOSABERES**, v.8, n.º 17, 2018.
- dos ANJOS, H. D. B. **Impactos da urbanização sobre as assembleias de peixes de igarapés de Manaus, Amazonas, Brasil**: processos ecológicos e perspectivas de conservação. 2022. Tese (Doutorado em Ciência Animal e Recursos Pesqueiros) – Curso de Ciência Animal - Universidade Federal do Amazonas, Manaus, 2022.
- BARRETO, A. S.; NOUR, E. A. B.; DOMINGUES, L. M. Avaliação de um sistema de tratamento de esgoto submetido a cloração visando reuso pela quantificação de microrganismos. **Revista DAE**, p. 18-22, 2014.
- BEZERRA, E. F.; CÂNDIDO, L. A.; MONTEIRO, T. F. Dinâmica do carbono orgânico em igarapés de microbacias intactas e manejadas na Amazônia Central. *In*: **Jornal de Iniciação Científica**. 14. 2007. Anais. Manaus: PIBIC CNPQ/FAPEAM/INPA.
- BRASIL. **Resolução n.º 357**, de 18 de março de 2005. Brasília: MMA. BRASIL. **Resolução n.º 430**, de 13 de maio de 2011. Brasília: MMA.
- BRINGEL, S. R. B. Origem da Bacia Amazônica. *In*: BRINGEL, S. R. B.; GUTIERREZ, D. M. D. (Org.) **Águas da Amazônia**: natureza e desafios contemporâneos. Manaus: INPA, 2024. p. 11-15.

CARDOSO, A. C. D. *et al.* Morfologia urbana das cidades amazônicas: a experiência do Grupo de Pesquisa Cidades na Amazônia da Universidade do Federal do Pará. **Revista Brasileira de Gestão Urbana**, n. 12, e20190275, 2020.

CORREA, D. L. **Análise da susceptibilidade a inundações na bacia hidrográfica do rio Uraim, Paragominas, PA.** 2017. Dissertação (Mestrado em Recursos Hídricos) – Curso de Recursos Hidricos - Universidade Federal do Pará, Belém, 2017.

ESTEVEVES, F. A. **Fundamentos da Limnologia.** 2 ed. Rio de Janeiro: Interciência, 1998.

FASSONI-ANDRADE, A. *et al.* (Org.) **Hidrologia da Amazônia, visto do espaço: avanços científicos e desafios.** 2023. p. 18-24.

FERREIRA, S. M.; VALLINA, K. A.. L. O programa social e ambiental dos igarapés de Manaus (PROSAMIN): a construção de uma espacialidade. *In: Seminário Nacional de Serviço Social. Trabalho e Política Social.* 1. 2015. Santa Catarina.

FIGUEIREDO, R. O. Estudos em pequenos riachos amazônicos (igarapés) e suas bacias alteradas por desmatamento e atividades agrícolas. *In: Congresso Latino-Americano de Ecologia.* 3. 2009. Anais. EMBRAPA AMAZONIA ORIENTAL.

GAMA, A. S.; MACIEL, M. N. M; WATRIM, O. S. Análise da dinâmica do uso da terra e seus reflexos na cobertura vegetal na microbacia hidrográfica do igarapé do sete, no município de Paragominas, estado do Pará. *In: Seminário de Iniciação Científica.* 3. 2007. Pará. EMBRAPA CPATU

GONÇALVES, S. F. S. **Relações entre os sistemas de produção agropecuário adotados e a qualidade da água em Igarapés Amazônicos de duas bacias hidrográficas na região de Paragominas (PA).** 2007. Dissertação (Mestrado em Ciências Ambientais) – Curso de Ciências Ambientais - Universidade Federal do Pará, Belém, 2007.

GROBE, C. M. P. Manaus e seus igarapés: a c construção da cidade desejada e sua natureza velada. *In: Encontro Internacional de História & Parcerias.* 2. 2019. Rio de Janeiro. Anais eletrônicos.

IBGE. Instituto Brasileiro de Geografia e Estatística. **Censo 2010.**

IBGE. Instituto Brasileiro de Geografia e Estatística. **Censo 2022.**

IBGE. Instituto Brasileiro de Geografia e Estatística. **Normas de apresentação Tabular.** 3 ed. Rio de Janeiro: IBGE, 1993.

LAGES, A.S. *et al.* Parâmetros físicos (temperatura, condutividade elétricas e turbidez) na avaliação de corpos de água impactados na área urbana da cidade de Manaus, AM. **Brazilian Journal of Development**, v.8, n.º 11, p. 71776-71785, 2022.

LIMA, L. C. *et al.* Determinação da concentração de sólidos dissolvidos totais por meio da medição da condutividade elétrica. *In: Congresso Brasileiro de Engenharia Agrícola.* 54. 2017. Alagoas.

MELO, V. S.; MACHADO, R. A. Efeito da pluviosidade nas características físico- químicas de um igarapé de área urbana do oeste da Amazônia – estudo de caso. **Enciclopédia Biosfera**, v. 21, n.º 50, p. 49-62, 2024.

MURPHY, S. F. *et al.* Urbanization and water management control stream water quality along a mountain to plains transition. **Water Resources Research**, n.º 60, e2023WR035633. 2024.

NEVES, M. N. B. *et al.* Análise temporal quali-quantitativa da água em relação ao processo de desativação de barramento de água na microbacia do igarapé Parariquara, no município de Paragominas – PA. *In: Congresso Brasileiro de Geologia de Engenharia e Ambiental*. 17. 2022. Anais eletrônicos.

NUCCI, J. C. Análise sistêmica do ambiente urbano, adensamento e qualidade ambiental. **Revista Ciências Biológicas e do Ambiente**, v. 1, n.º 1, p. 73-88, 1999.

PARAGOMINAS. Secretaria Municipal de Planejamento. **Divisão Setorial – Bairros**. 2023.

PIVELI, R. P. **Oxigênio dissolvido e matéria orgânica**. São Paulo: USP.

ROCHA, T. S. *et al.* Análise de qualidade das águas do igarapé Tucunduba dentro da área urbana da UFPA, *campus* Guamá – Belém (PA). **Revista Foco**, v. 16, n.º 9, p. 01-23, 2023.

RODRIGUES, T. E. *et al.* **Caracterização e classificação dos solos do município de Paragominas, estado do Pará**. Belém: Embrapa Amazônia Oriental, 2003.

SANTOS, A. S.; FERREIRA, S. J. F. **Avaliação de variáveis da qualidade da água de igarapés de origem em reserva florestal e sob diferentes usos**. *In: Congresso de Iniciação Científica do INPA – CONIC*. 3. 2014. AMAZONAS.

SANTOS, F. **Urbanização altera qualidade da água de igarapés no Amazonas com nascentes na Reserva Ducke**. Manaus: FAPEAM, 2017.

SANTOS, G. P. *et al.* Efeitos da integridade da zona ciliar e sua influência na qualidade da água de igarapés urbanos em Santarém-PA, Amazônia, Brasil. **Revista Brasileira de Geografia Física**, v. 14, n.º 7, p. 4035-4055, 2021.

SANTOS, Z. *et al.* Análise do índice de qualidade de água em função da sazonalidade na microbacia do Irurá no município de Santarém-Pará. **Revista Ibero-Americana de Ciências Ambientais**, v. 12, n.º 5, p.314-326, 2021.

SiBBr. Sistema de Informação sobre a biodiversidade brasileira. *Brachiaria arrecta* s/d. Disponível em: [Brachiaria arrecta | SiBBr](#), Acesso em: 18 jan. 2025.

SILVA, M. S. R. *et al.* Desafios para a gestão das águas na região amazônica. *In: Simpósio Brasileiro de Recursos Hídricos*. 20. 2013. Rio Grande do Sul. Anais eletrônicos.

SILVA, M. S. R.; MIRANDA, S. A. F.; SANTANA, G. P. Bacia hidrográfica do rio Amazonas: condições de sua água versus resolução n.º 357/CONAMA/2005. **Scientia Amazonia**, v. 6, n.º 2, 0p. 83-90, 2016

SILVA, P. M. B, M.; SILVA, M. M. Igarapés impactados pela ação antrópica no município de Uruará, Pará. **Enciclopédia Biosfera**, v.17, n.º 31, p. 103-114. 2020

SILVA, P. S. *et al.* Influência do uso da terra sobre a qualidade da água de quatro igarapés na Amazônia Oriental: variabilidade espacial e sazonal de pH, condutividade elétrica, oxigênio dissolvido, e turbidez. *In: Congresso de estudantes e bolsista do Experimento LBA*. 2. 2005. Amazonas. Anais eletrônicos.

SILVA, R. F. S. *et al.* Dinâmica urbana e qualidade hídrica: análise comparativa da água de escoamento pluvial em zonas comerciais e residenciais do município de Fortaleza, Ceará – Brasil. *In: Congresso Internacional de Engenharia Ambiental*. 3. 2024. Rio Grande do Sul. Anais eletrônicos.

SILVA, T. B. **Caracterização da água de igarapés na região de Itacoatiara – AM, médio Amazonas**. Relatório Técnico. Manaus: UFAM, 2011.

SILVA, T. M.; SOUZA, L. E. S.; da SILVA, E. J. **Degradação ambiental de um igarapé amazônico em seu trecho urbano**. Roraima: IFRR, Forint, 2024.

SILVEIRA, F. F. **Flora campestre**. Porto Alegre: UFRGS. Laboratório de Estudos em Vegetação Campestre. 2020.

SOUSA, S. H. S. **Geotecnologias aplicadas à análise socioambiental do alto curso da Bacia Hidrográfica do Rio Uraim (Paragominas-PA): contribuições aos estudos integrados**. 2017. Trabalho de Conclusão de Curso (Tecnologia em Geoprocessamento) Curso de Geoprocessamento - Universidade Federal do Pará, Belém, 2019.

SOUZA FILHO, E. A.; BATISTA, I. H.; ALBUQUERQUE, C. C. Levantamento de aspectos físico-químicos das águas da microbacia do Mindu em Manaus- Amazonas. **Revista Geográfica de América Central**, n.º 53, 2019.

SOUZA, D. F. *et al.* Delimitação e caracterização morfométrica da bacia hidrográfica do RIACHO DO Navio, Pernambuco, a partir de dados SRTM processados no QGIS. **Revista de Geografia Física**, v. 145, n. 03, p. 1530-1540, 2021.

SOUZA, J. M. *et al.* Uniformidade de distribuição de fertilizantes e água em um sistema de irrigação por microaspersão em bananeira. *In: Congresso Brasileiro de Engenharia Agrícola*. 69. 2020. *On-line*.

SOUZA, R. A. P. ; da SILVA, M. S. R.; MIRANDA, S. A. F.; NASCIMENTO, C. R. Diagnóstico da qualidade da água dos igarapés da bacia do Bolívia, Manaus/AM. *In: Jornada de Iniciação Científica PIBIC CNPQ/FAPEAM/INPA*, 2007.

STROKAL, M. *et al.* Urbanization : an increasing source of multiple pollutants to rivers in the 21st century. **Urban Sustainability**, v.1, n. 24. 2021.

TARGA, M. S. *et al.* Urbanização e escoamento superficial na bacia hidrográfica do Igarapé Tucunduba, PA, Brasil. **Revista Ambiente & Água**, v. 7, n.º 2, p.120-141, 2012.

VASCONCELLOS, R. C.; BELTRÃO, N. E. S.; SILVA, S. M. A. Potencialidade da aplicação do Índice de Vegetação por Diferença Normalizada (NDVI) em políticas de regularização ambiental: um estudo em Paragominas, Pará, Brasil. *In: Congresso Amazônico de Meio Ambiente e Energias Renováveis*. 2. 2016. Pará. Anais eletrônicos.

VENTURIERI, A. *et al.* Utilização de imagem Landsat e CBERS na avaliação de mudança do uso e cobertura da terra e seus reflexos na qualidade da água em microbacia hidrográfica do município de Paragominas, Pará. *In Simpósio de Sensoriamento Remoto*. 12. 2005. Goiás. Anais eletrônicos.

WACHHOLZ, F.I *et al.* O uso da terra após a duplicação da rodovia Manoel Urbano (AM-070) e sua influência na qualidade da água dos igarapés (Iranduba- AM). **Revista GeoUECE**, v. 9, nº especial, p. 50-62, 2020.

ARTIGO 5

First study of ammonia (NH_3) contained in the Paragominas stream in the municipality of the same name, southeastern Pará

RESUMO

A amônia não ionizada ou livre é a substância nitrogenada mais tóxica no ambiente aquático, e a ausência de informações sobre ela causa uma deficiência na avaliação da qualidade da água. Essa foi a lacuna que norteou esta pesquisa, uma vez que a geração e o descarte desses dados podem auxiliar na gestão integrada ou não integrada da qualidade da água do Igarapé Paragominas. O objetivo é identificar a presença ou ausência no trecho urbano, caracterizar a origem antrópica e verificar se três parâmetros associados à qualidade da água atuam ou não sobre a amônia não ionizada ou livre. O método utilizado foi hipotético-dedutivo com abrangência quantitativa e qualitativa de natureza observacional. Os dados obtidos e analisados indicaram que nas cinco áreas analisadas, a ocorrência de amônia não ionizada ou livre indicou. Indicaram ainda que em áreas onde a aglomeração populacional é menor, a concentração desse gás, em mg/L, também é menor (A_1 , $0,13 \pm 0,04$) e, proporcionalmente, à menor quantidade de efluentes que entram na área de amostragem; à medida que esse cluster cresce, também cresce a concentração (A_2 , $0,26 \pm 0,04$; A_3 , $0,37 \pm 0,17$; A_4 , $0,81 \pm 0,44$), dependendo da ocorrência inversa; a temperatura da água apresentou tendência crescente (A_4 , $26,75 \pm 0,92$); a concentração de OD em mg/L foi mais efetiva em A_2 ($2,27 \pm 0,81$), em oposição à identificada em A_5 ($1,50 \pm 0,36$). Por fim, observou-se que o crescimento da aglomeração populacional ocorreu em A_2 , A_3 e A_4 , associado à deficiência de saneamento básico, os três parâmetros componentes da qualidade da água, atuam direta e indiretamente, na concentração de amônia não ionizada ou livre, o que ocasiona problemas ao córrego Paragominas e a falta de informações sobre isso, determina uma gestão ineficiente quanto à qualidade da água neste afluente, na margem direita, do rio Uraim.

Palavras-chave: Efluentes. Crescimento demográfico. Gestão da qualidade da água.

ABSTRACT

Non-ionized or free ammonia is the most toxic nitrogenous substance in the aquatic environment, and the absence of information about it causes a deficiency in the assessment of water quality. This was the gap that guided this research since the generation and disposal of these data can help in the integrated or non-integrated management of the water quality of the Igarapé Paragominas. The objective is to identify the presence or absence in the urban section, characterize the anthropic origin and verify whether or not three parameters associated with water quality act on non-ionized or free ammonia. The method used was hypothetical-deductive with quantitative and qualitative coverage of an observational nature. The data obtained and analyzed indicated that in the five areas analyzed, the occurrence of non-ionized or free ammonia indicated. They also indicated that in areas where the population agglomeration is smaller, the concentration of this gas, in mg/L, is also lower (A_1 , 0.13 ± 0.04) and, proportionally, to the smaller amount of effluents that enter the sampling area; as this cluster grows, so does the concentration (A_2 , 0.26 ± 0.04 ; A_3 , 0.37 ± 0.17 ; A_4 , 0.81 ± 0.44), depending on the inverse occurrence; the water temperature showed

an increasing trend (A_4 , 26.75 ± 0.92); the DO concentration in mg/L was more effective in A_2 (2.27 ± 0.81), as opposed to that identified in A_5 (1.50 ± 0.36). Finally, it was observed that the growth of the population agglomeration occurred in A_2 , A_3 and A_4 , associated with the deficiency of basic sanitation, the three component parameters of water quality, act directly and indirectly, in the concentration of non-ionized or free ammonia, which causes problems to the Paragominas stream and the lack of information about this, determines an inefficient management regarding the quality of water in this tributary, on the right bank, of the Uraim River.

Keywords: Wastewater. Population growth. Water quality management.

INTRODUCTION

The lack of data on water quality in many Brazilian municipalities makes it difficult for municipalities to manage water resources in the city. The 5,540 Brazilian municipalities have serious problems regarding this quality, due to the economy (UNESCO, 2025) and social (TUNDISI, 2008) disordered development. Another problem is the deficient basic sanitation infrastructure (ANA, 2025) associated with wastewater discharged into surface water (BRAZIL, 2005) that causes a decrease in what is conventionally called conserve today so as not to lack tomorrow. However, this has not yet occurred, and this causes a gap in the context of the basic needs of communities: the right to quality water (ALMEIDA; KLUSKA; ALMEIDA, 2014).

Water quality, in terms of wastewater discharge, in Brazil has guidelines defined by its own legislation (BRAZIL, 2011). Municipalities also do so (PARAGOMINAS, 2014). However, the growth of populations that occurs in them and their concentration in the urban area (IBGE, 2016), has caused a severe water management problem, as in the case of the so-called integrated management (SILVA; PORTO, 2003). This type of management is one of the tools that meets goal six of the Sustainable Development Goals and ensures the right to the natural resource for future generations, in addition to increasing water security (SILVA *et al.*, 2019).

Undoubtedly, water quality is analyzed under component parameters of physical (e.g., temperature) and chemical properties such as pH, dissolved oxygen – DO; nitrogenous compounds such as non-ionized or free ammonia NH_3 (BRAZIL, 2005; 2011) To identify and measure them, there are several mechanisms such as kits for analysis. With all this, the gap of ignorance is still high (MOEIZADEH; YONG; WITHANA, 2024). Another problem for water quality is the absence of studies that indicate the characteristics of the areas of influence and the places where surface water is collected (PASSOS *et al.*, 2019).

The biggest problem of NH_3 , in the aquatic environment, is its toxicity since it is dependent on the biogeochemical nitrogen cycle (EDWARDS *et al.*, 2024; WANG *et al.*, 2020). Another fact that is still unclear is the real value of non-oxidized ammonia, as an indicative factor and not the sum with ionized ammonia, since its toxicity is lower in surface waters NH_3 (IP; CHEW; RANDALL, 2001). In addition, there is a decrease in the levels of OD, in relation to the presence NH_3 (SERAFIN; ZABINONI FILHO, 2009). Another variable that, in Brazil, acts as an indicator of water quality, the water temperature and that acts on the levels of NH_3 (IVAN *et al.*, 2024).

All knowledge about its genesis from two main sources: natural and anthropic must be the object of constant observations, with special attention to the second (DANTAS *et al.*, 2022). Especially in municipalities where economic and population development increases density and urban agglomerations, and where recreation areas are located on the periphery (LLOYD *et al.*, 2024; SANDU *et al.*, 2022; WANG *et al.*, 2020). A major problem lies in the lack of attention that the surface waters of urban tributaries pay in relation to what it discharges into the main river of NH_3 (ANH *et al.*, 2023; LIANG *et al.*, 2025).

All these approaches are associated with the Paragominas stream, in the municipality of the same name, Pará, Brazil. The most serious is the absence of hydrological information regarding the quality of the water due to the presence of it, which generates insufficient management of this water resource. This justified and increased the relevance of this research, whose objectives were: 1) to identify the presence or absence of from the beginning of the urban perimeter to the flow into the main river; 2) to characterize the anthropogenic influences of urbanized areas on the water quality of this stream in the areas of water sampling; 3) Check the actions of pH, dissolved oxygen (DO) and water temperature on this gas.

MATERIAL AND METHODS

PHYSIOGRAPHY OF THE AREA

The municipality of Paragominas (Figure 1), located in the southeast of Pará (2°59'S; 47°21'W), at an altitude of 89 m (ALVES; OAK; SILVA, 2014), occupies 31.1% (19,343 km²) of the Capim River integration region (PARÁ, 2023). Of this area, 29.7 km² are urbanized, and 21.34% of the households are connected to sanitary sewage.

The population was equivalent to 105,550 inhabitants in 2022, of which 96. 150 inhabitants in the urban area, and 9,400 in the rural area (IBGE, 2023).

Figure 1. Location of the municipality of Paragominas, Pará State, Brazil.



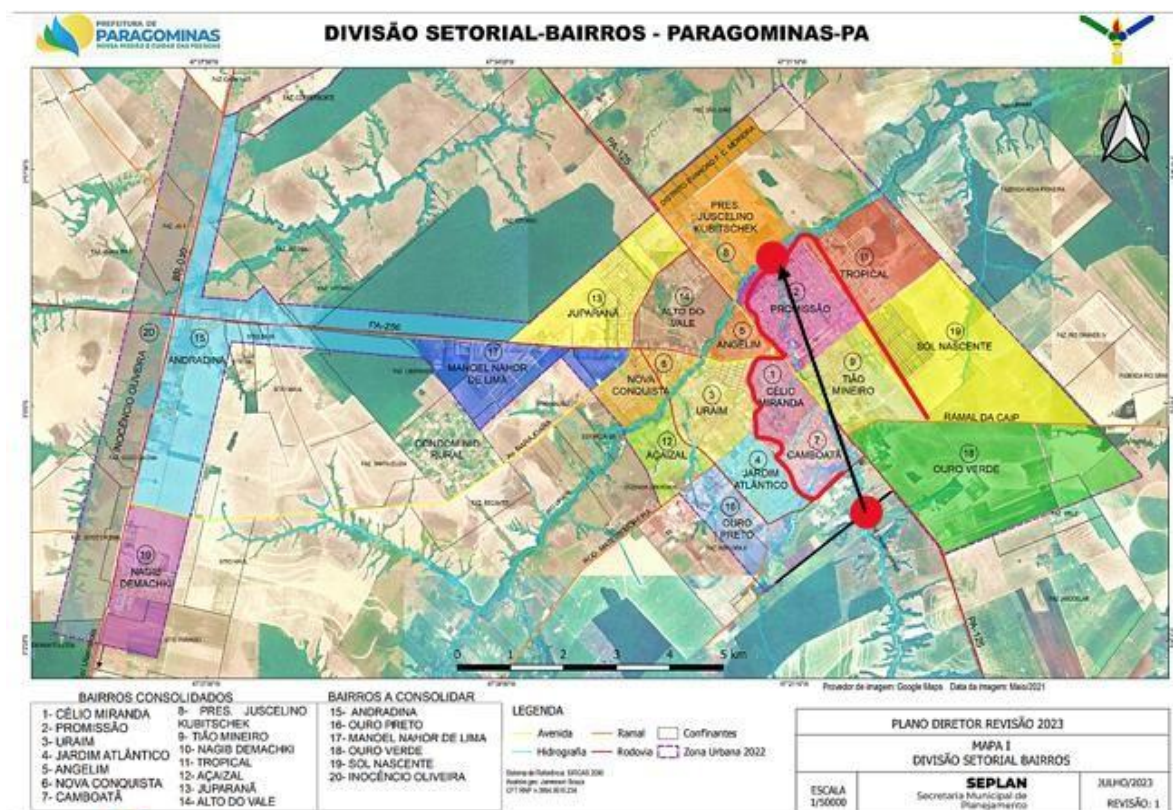
Elaboration: Silva, G R. (2025).

The climate in the Köppen classification is equatorial *Ah* Expressive, rainy tropical and dry logo. According to Thornthwaite's classification, the climate will be humid tropical, with significant droughts (RODRIGUES *et al.*, 2020), and the current vegetation corresponds to secondary forests in stages of development such as capoeira. This is a result of the use and occupation of the soil, in the face of deforestation to support growing cattle ranching. Municipal Law No. 870 (PARAGOMINAS, 2014) governs municipal sanitation

Research area

The watershed of the Paragominas stream (Figure 2) has an area equivalent to 66 km², and a perimeter equal to 51 km (PARAGOMINAS, 2014) and is a tributary of the right bank of the Uraim River, and has, in the rural course, 11 dams (RODRIGUES *et al.*, 2020). In this context, the chosen area begins at the Constantino Pereira do Sacramento Highway, former Pioneers Highway and extends to Padre Carvalho Street (≈ 4.4 km, in the direction M \rightarrow J). The flow of this stream into the Uraim watershed is 500 m from this street, at the following geographical coordinates: 046°49'48.0" W; 02°48'14.9"S.

Figure 2 - Area of the urban stretch of the Paragominas stream, from the Constantino Pereira do Sacramento Highway to the flow into the Uraim River, right bank, in the municipality of the same name. Pará State. Brazil.



Subtitles: ● Paragominas stream, urban section; ↗ extension of the area. **Source:** adapted from the original contained in Paragominas (2023).

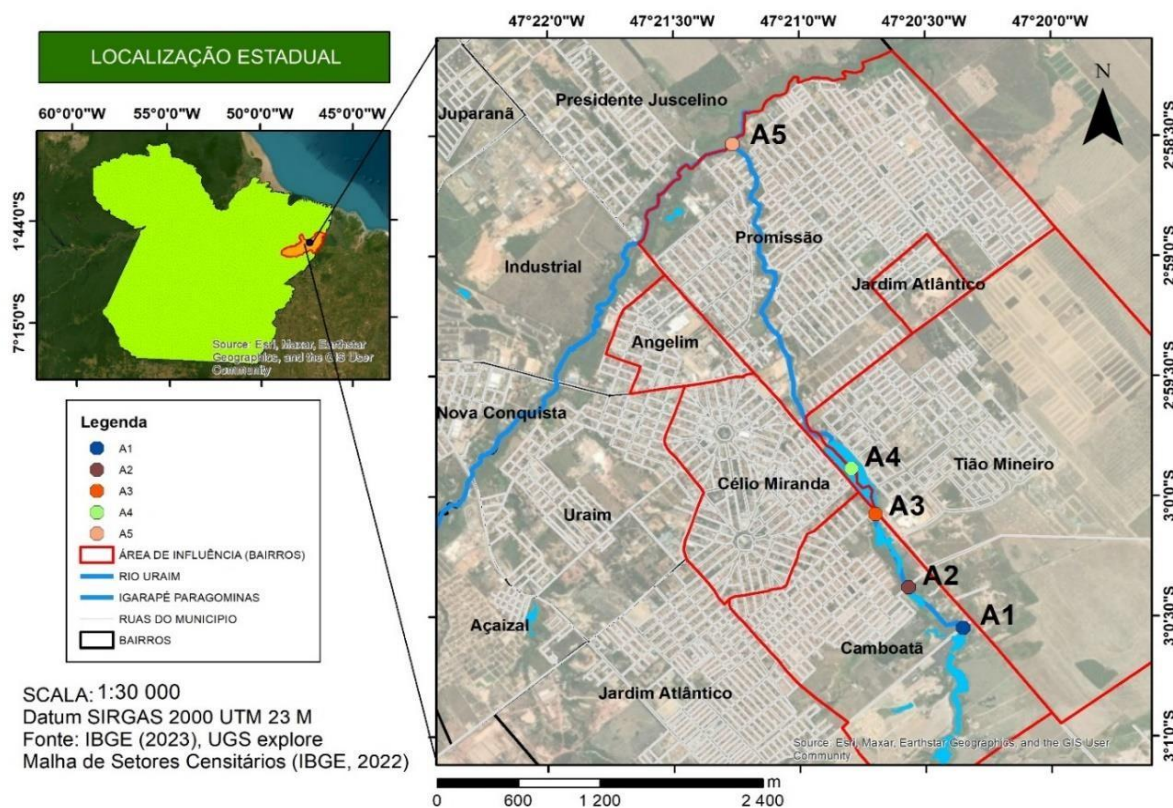
The water body under analysis does not present a classification. However, the resolution of the National Council for the Environment - CONAMA (BRASIL, 2005), Chapter II – Classification of Water Bodies, Section I – Fresh Waters, article 4, item III, class 2, waters may be destined: b) for the protection of aquatic communities; c) primary contact recreation (swimming); d) irrigation of... parks and gardens; e) fishing activity. The anthropogenic activities contained in items c, d, and e, are linked to both A1 and A2.

Selected areas for sampling

In this extension, five areas were selected, based on the criterion of population clusters, from the smallest to the largest, identified as A1 - Constantino Pereira do Sacramento Highway, 850 m from the PA 125 Highway, towards W → E, from the Fazendinha area; A2 - Selecta Avenue, residential complex (Camboatã neighborhood), which previously housed numerous sawmills; A3 - confluence of Gregório Santos Araújo Street (Camboatã neighborhood); A4 – Green Lake (Tião

Mineiro neighborhood); A5 – Bridge over Padre Carvalho Street, in the Promissão neighborhood (Figure 3).

Figure 3 – The five selected areas in the urban stretch of the Paragominas stream, in the homonymous municipality. Pará State. Brazil



Elaboration: Silva, G R. 2025.

The emergence of this area comes from an urbanization of this area where an open-air dump prevailed, which was subjected to dredging services, enlargement of the original bed. It currently has an extension equal to 1000 m (PARAGOMINAS, 2014), without the maintenance of the original or secondary riparian forest. In the Master Plan for the Development of the Municipality – PDDM (PARAGOMINAS, 2020).

The conservation of the riparian forest, in article 25, was cited in the PDDM, obedience to the conservation of the Permanent Protection Area (APP), the ranges established by the Forest Code, Law No. 12,651 (BRASIL, 2012). The protection of water resources, on the other hand, is cited in Municipal Law No. 1123 (PARAGOMINAS, 2023) which establishes the Municipal Development Master Plan of Paragominas. In Law No. 765 (PARAGOMINAS, 2015), in chapter III, of the

principles, article, 5, item VIII, it mentions that there will be protection, preservation and recovery of ecosystems.

Include here the aquatic ecosystems, especially the Paragominas stream, a tributary of the right bank of the Uraim River Microbasin. In chapter III, of Environmental Control, section III, of water pollution, the guidelines for the discharge of effluents into surface waters, it states that this can only occur if there is obedience to the standards established by law, in the three legislative spheres: federal, state, and municipal.

METHODS

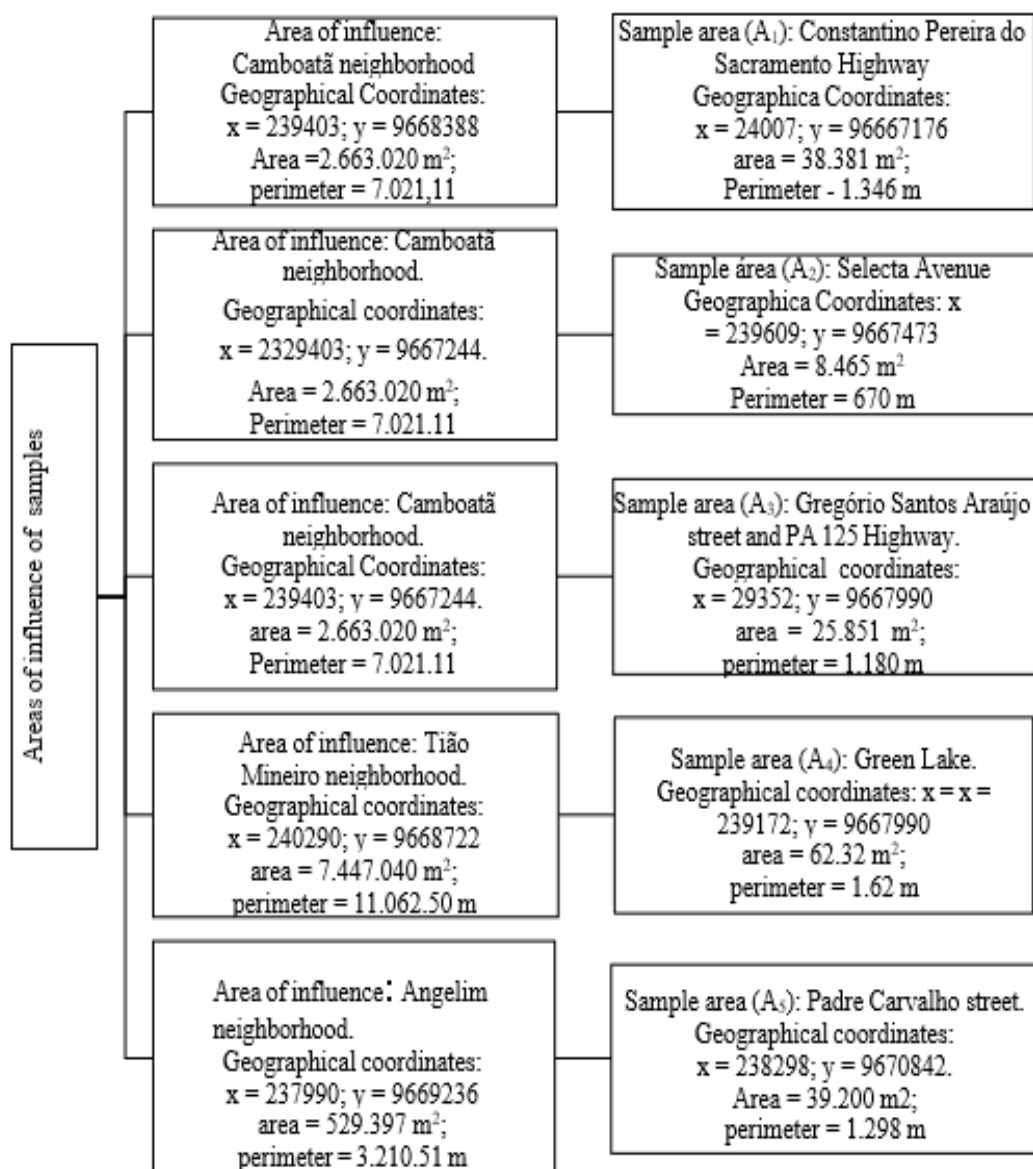
The method used was hypothetical-deductive in view of the information gap (PRODANOV; FREITAS, 2013) about the water quality of this stream with the water management bodies of the municipality of Paragominas. This method was associated with quantitative and qualitative comprehensiveness with an observational nature (PEREIRA *et al.*, 2018). In this case, it was to identify the concentration of non-ionized or free ammonia (NH_3) in the surface waters of the urban stretch of the Paragominas stream, due to the high toxicity it presents in surface waters.

OBTAINING DATA

Primary

The primary data were obtained from water sampling in the five areas of the urban stretch of the Paragominas stream. It involved five areas of influence: Constantino Pereira do Sacramento Highway, Camboatã neighborhood, Tião Mineiro neighborhood, Célio Miranda neighborhood, and Promissão, all of which have domestic effluent flow to the areas where the collections were conducted. In the selected urban section, the five selected areas were enumerated (Figura 4), according to the sectorization of the neighborhoods (PARAGOMINAS, 2023).

Figure 4 – Area of Influence and collection with the respective numbers and denominations of the neighborhoods that border the Paragominas stream, in the municipality of the same name. Pará State. Brazil.



Source: authors (2025).

The water sampling followed the parameters established by the Standard Methods for the Examination of Water and Wastewater (APHA, 1985). For sampling, 10 glass borosilicate flasks ($V = 500$ mL) were used, with a screw-on cap and coated with aluminum foil. The collection was conducted in the morning, starting at 07:00, in the dry-rainy transition period, due to the upward trend and possible gaseous atmospheric loss. Then, they were stored in a cooler to be transported to the Environmental Quality Laboratory (LQA), where they were stored in refrigerators at 4°C, for analysis that took place the day after collection.

Laboratory tests

Laboratory analyses took place on February 18, 2025. To conduct this action, the Amônia Tester, AKSO brand, was used, which uses the Nessler method to identify the quantity of ammonia in the five areas of the urban stretch of the Paragominas stream. The temperature of the sampled water at 25 °C, with a measurement range between 0.00 and 5.00 ppm with accuracy (± 0.10 ppm + 5%) with a sample volume equal to 10 mL. The wavelength equivalent to 455 nm. The basis for these analyses was supported by the established guidelines National Health Foundation (FUNASA, 2013).

Secondary data

To obtain secondary data, the following were accessed: *Links* electronic products that store publications on the subject of this research, especially ammonia in surface waters: Environment & Water; Brazilian Agricultural Research Corporation (EMBRAPA), Portal of the Coordination for the Improvement of Higher Education Personnel (CAPES) via CAFe, Google Scholar, PLOS ONE, ResearchGate, Science Direct; Virtual Journal of Chemistry, *Web of Science*, among others.

The time limit comprised the last 54 years, which were divided into five decades and four years, to expand the number of publications with the objective of better supporting the discussions, based on research and publications inherent to the theme of this research.

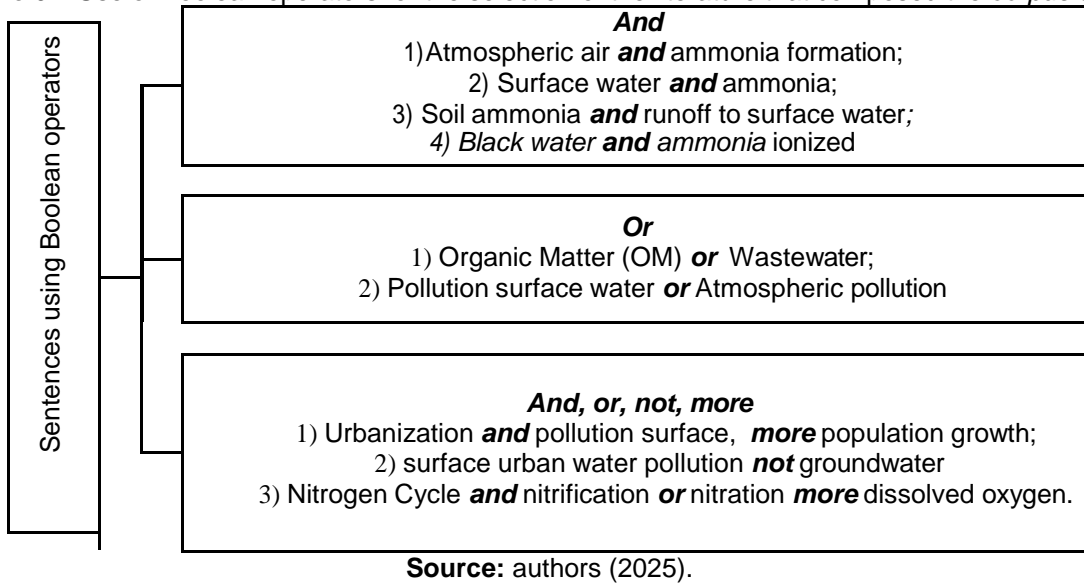
These periods allowed an effective interpretation and evolution of studies and national legislation about this gas in the aquatic environment and its implications for water quality and its inhabitants (Figure 5).

Figure 5 - The four and a half decades used to compose the *corpus* of this research.



To compose the *corpus* of this research, it was necessary to apply Boolean operators. Their use is justified because they allow and facilitate the combination of words of interest (FREITAS *et al.*, 2023). In this study, they were used, both in isolation and in association (Figure 6).

Figure 6 – Use of Boolean operators for the selection of the literature that composed the *corpus* of this



STATISTICAL ANALYSIS OF THE DATA

Due to the condition of non-parametric data, Analysis of Variance (ANOVA) was used as a criterion, followed by the Kruskal-Wallis's test, with the BioEstat 5.0 software (IDM, 2023), to verify the difference between the means with the use of the *Paleontological Statistics software* (PAST, 2024). For the Principal Component Analysis, the Kaiser criterion (eigenvalues < 1) was applied.

RESULTS

The analysis of the data obtained indicated that, in the five areas analyzed, the concentrations of non-ionized or free ammonia are affected by pH, temperature and DO (Table 1).

Table 1 – Values for the ammonia averages, Hydrogen potential (pH), Temperature and Dissolved Oxygen (DO), measured in the five areas of the urban stretch of the Paragominas stream, in the homonymous municipality. Pará State. Brazil.

Areas Analyzed	Ammonia-Free. (mg/L)	Water T (°C)	pH --	DO (mg/L)
Constantino Pereira do Sacramento Highway.	0.13	23.65	5.42	2.04
Selecta Avenue	0.26	26.20	6.19	2.27
Confluence of Gregório Santos Araújo Street	0.37	23.95	5.58	1.70
Green Lake	0.81	26.75	5.37	2.07
Padre Carvalho Street	1.21	25.30	6.53	1.50
$p < 0.05$				

Source: authors (2025)

It is observed that the p value, is significant to the action of the three variables on the concentration of ammonia in the five areas analyzed ($p < 0.00193$). The eigenvalues found explain 82.2% of the variations in the data obtained and their action on the concentration of non-ionized ammonia (Table 2).

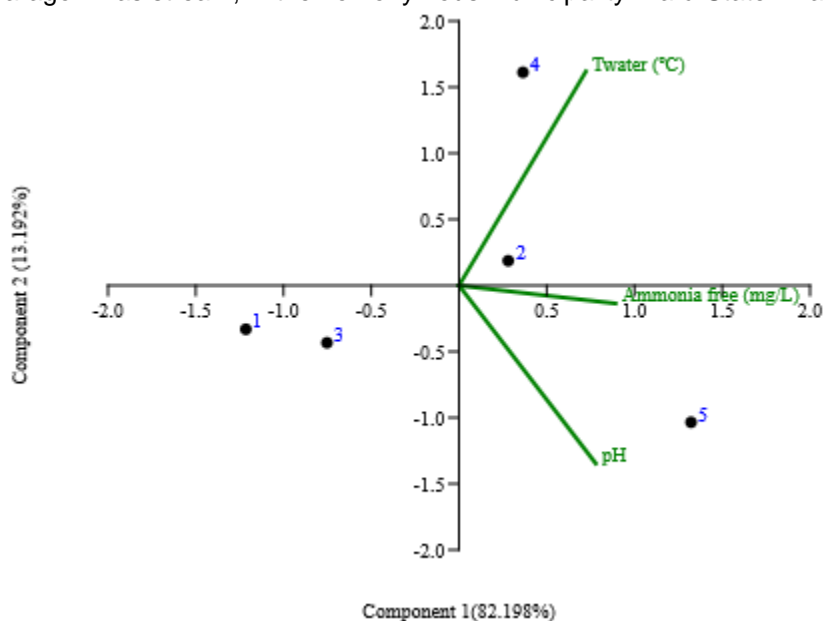
Table 2 – Eigenvalues and percentages of variations of the principal components between non-ionized or free ammonia, temperature, and pH in the five areas analyzed in the urban stretch of the Paragominas stream, in the municipality of the same name. Pará State. Brazil.

Main Components	Eigenvalue	(%) Variation
1	1.86589	82.198
2	0.299467	13.192
3	0.104646	4.61

Source: authors (2025)

It can be seen that non-ionized or free ammonia showed tendencies for increases or decreases, under the action of temperature and pH, especially at As (Figure 7).

Figure 7 – Effect of pH temperature on ammonia concentration, in the five areas analyzed in the urban stretch of the Paragominas stream, in the homonymous municipality. Pará State. Brazil.



Legend: 1 - RCPS, Constantino Pereira do Sacramento Highway (A_1); 2 - Selecta Avenue (A_2); 3 - Camboatã neighborhood (A_3); 4 - Green Lake (A_4); 5 - Padre Carvalho street (A_5). Source: authors (2025).

It was also verified that the concentration of ammonia tends to variations, as a function of temperature and DO supply. In this case, the variability between them is 85.09%, and are explained by these three components (Table 3).

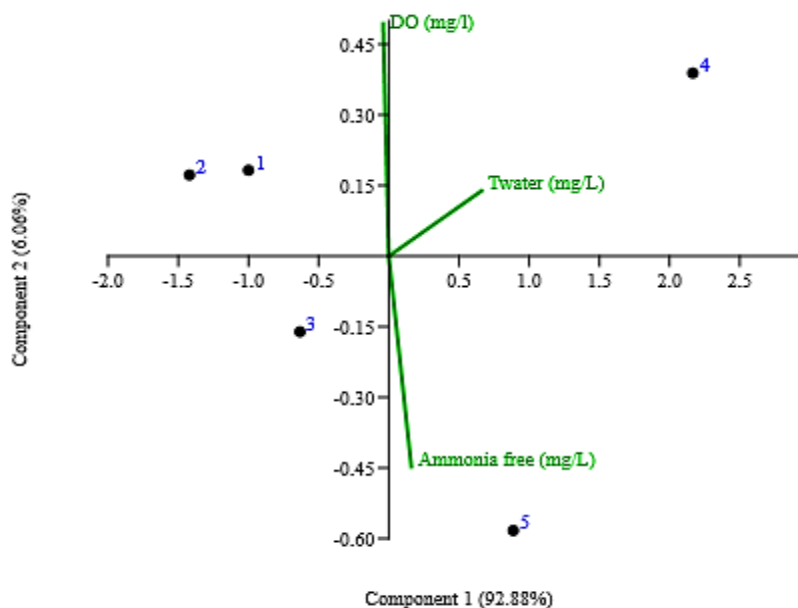
Table 3 - Eigenvalues and percentages of variations of the principal components between non-ionized or free ammonia, temperature and DO supply, in the five areas analyzed in the urban stretch of the Paragominas Stream, in the municipality of the same name. Pará State. Brazil.

Main Components	Eigenvalue	(%)Variation
1	2.22282	92.878
2	0.144998	6.0586
3	0.0254413	1.063

Source: authors (2025).

The significance index ($p < 0.00193$) indicates that there is a difference between the means of the values obtained, and that the actions on non-ionized or free ammonia are effective both by temperature and by DO (Figure 8).

Figure 8 – Action of temperature and DO on ammonia, in the five areas of the analyzed urban stretch of the Paragominas stream, in the homonymous municipality. Pará State. Brazil.



Legend: 1 = A₁ – Constantino Pereira do Sacramento Highway; 2 = A₂ – Selecta Avenue; 3 = A₃ – Confluence of Gregório Santos Araújo Street with PA 125 Highway; 4 = A₄ – Lago Verde; 5 = A₅ – Padre Carvalho Street. Source: authors (2025).

Figure 8 shows that low temperature is one of the environmental factors that act positively on the concentration of DO in A₁ and A₂. The concentration of DO was higher at A₄. On the other hand, the concentration of non-ionized or free ammonia tends to decrease in A₃. The temperature acted on the A₄ and A₅, in a slightly more effective way.

The action of pH and DO on the concentration of the NH_3 . The variance index of 68.73% better explains the relationship between these three variables (Table 4).

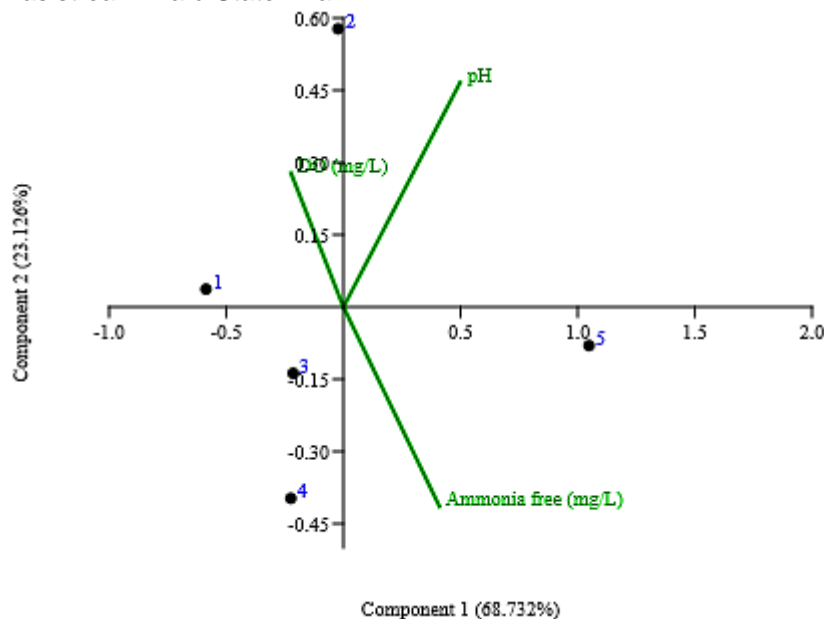
Table 4 - Eigenvalues and percentages of variations of the principal components between non-ionized or free ammonia, pH and DO supply, in the five areas analyzed in the urban stretch of the Paragominas Stream, in the municipality of the same name. Pará State. Brazil.

Main Components	Eigenvalue	(%)Variation
1	0.385093	68.732
2	0.12957	23.126
3	0.0456166	8.1418

Source: authors (2025).

The significance index ($p < 0.00193$) indicates that there is a difference between the means of the values obtained, and that the actions on non-ionized or free ammonia, as a function of pH, caused a rapid growth of this gas, were more effective in A₂. DO, on the other hand, reduces the concentration of NH_3 in A₅ (Figure 9).

Figure 9 – Role of the variables that make up the parameters of water quality analysis on the concentration of NH_3 . Paragominas stream. Pará State. Brazil.



Legend: 1 - Constantino Pereira do Sacramento Highway (A₁); 2 - Selecta Avenue (A₂); 3 - Camboatã neighborhood (A₃); 4 - Green Lake (A₄); 5 - Padre Carvalho street (A₅). Source: authors (2025).

DISCUSSIONS

ORIGIN

In the Paragominas stream, they tend to present numerous origins: physiological aspects of aquatic fauna and flora, soil, atmosphere, solid waste, population growth, among others. Study (QUEIROZ; BOEIRA, 2007) about the genesis in aquatic ecosystems, begins in the catabolic process of the aquatic inhabitants who excrete them. They can also come from soil, especially those where there is frequent use of fertilizers (agriculture and livestock) containing NH_3 (WISKICH; RAPSON, 2023) that release around 20% of this gas into the water. The burning of petroleum-based fuels, human excrement (SILVA, J.; SILVA, T.; BECKER, 2016) and vehicle catalytic converters, by 80% (GUIMARÃES; de MELLO, 2006).

In these ecosystems, has a bacteriological origin, as long as these microorganisms have been responsible for the residual degradation process of the OM that entered it NH_3 (MEDHI, 2021). Another source is wastewater, in which, in general, there is 55 to 60% ammonia nitrogen, a stage composed of NH_3 (HUANG; SHANG, 2006). In addition to wastewater, dumps that are established, whether temporary or permanent, in inappropriate locations (SILVA *et al.*, 2018) generate OM input, and this becomes a limiting factor for , which depends on the process of

mineralization and immobilization of this OM, in addition to the nitrogen cycle and consequent nitrification NH_3 (FRENEY; SIMPSON, 1981).

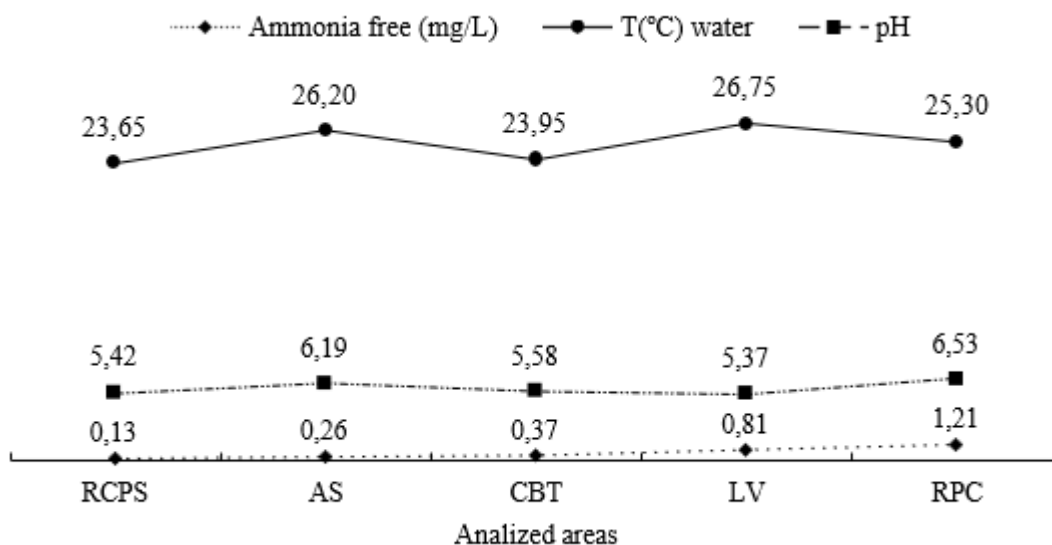
Sediments also contribute to the genesis of NH_3 . However, this will only occur if the micro bacterial concentration, responsible for the decomposition of the OM that, in this place, has accumulated. In this case, the form of degradation is from the mineralization of N_2 (EPA, 2025). Among the anthropogenic sources that are consistent with the economy of Paragominas, there is the use of synthetic fertilizers and livestock, the latter, via nitrogenous excreta (urea, uric acid). Such sources have already been identified from the study of the biogeochemical cycle (EDWARDS, *et al.*, 2024).

Maintenance of non-ionized or free ammonia in water

In the five areas analyzed, this chemical compound was identified. Its permanence in these places is linked to two variables, one physical and one chemical, which identify, in resolution 357 (BRASIL, 2005), the quality of the water: temperature and pH. The free form occurs when the second parameter has an alkaline character (dos REIS; MENDONÇA, 2009; SILVA *et al.*, 2014), this stage intensifies the toxicity of this gas in the aquatic environment, which compromises the aquatic fauna, and the water has two altered characteristics: odor and taste (MAZARI-HIRIART *et al.*, 2008; SAALIDONG *et al.* 2025), since, in the normal state, as for ammonia concentrations, the water is odorless and tasteless.

In the case of temperature and pH, at A₅, 25.30 °C and 6.53 were identified, respectively, for a concentration of 1.50 mg/L (Figure 10a). This indicates that the concentration of non-ionized or free ammonia (NH_3), was increased. Studies conducted on this relationship (BOYD; TUCKER, 1992; FELIX; CARDOSO, 2004) concluded that this creates a certain range of free ammonia equivalent to 0.60 mg/L. The range identified for ammonia non-ionized or free, in Paragominas, under these conditions of measured temperature and pH, was twice as high (1.21).

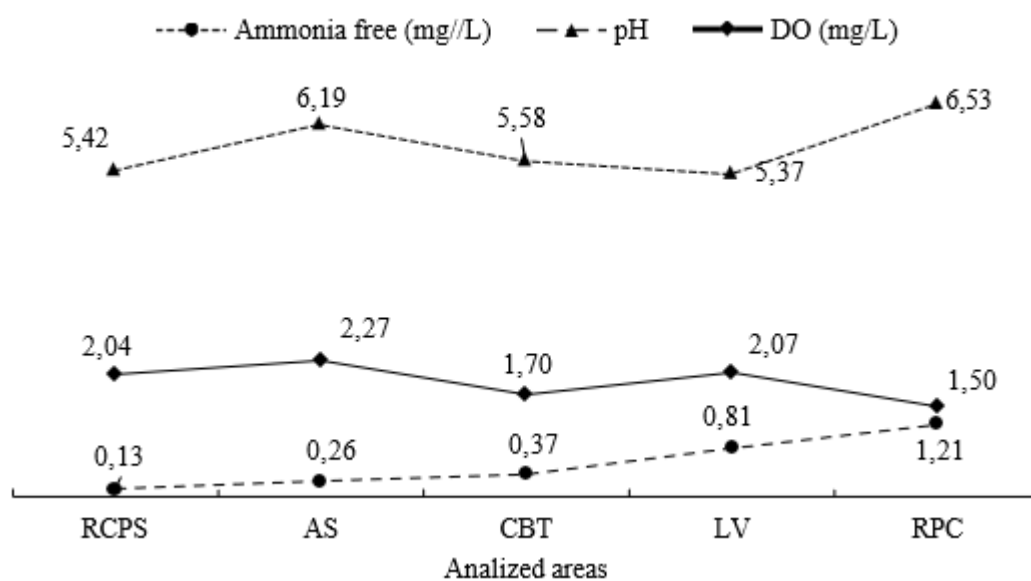
Figure 10a – Comparative data on the concentration of the non-ionized ammonia, and pH oscillations and trends of temperature variations in the five areas analyzed in the urban stretch of the Paragominas stream, in the homonymous municipality. Pará State. Brazil.



Legend: RCPS, Constantino Pereira do Sacramento Highway (A₁); Selecta Avenue (A₂); Camboatã neighborhood (A₃); Green Lake (A₄); Padre Carvalho street (A₅). Source: authors (2025).

As for the action of DO and pH in relation to the concentration of non-ionized ammonia in the five areas analyzed, the variation in the concentration of the first water quality parameter acts directly on the concentration of non-ionized ammonia (Figure 10b).

Figure 10b – Comparative data on the concentration of the non-ionized ammonia, pH oscillations and trends of DO concentrations in the five areas analyzed in the urban stretch of the Paragominas stream, in the homonymous municipality. Pará State. Brazil.



Legend: RCPS, Constantino Pereira do Sacramento Highway (A₁); Selecta Avenue (A₂); Camboatã neighborhood (A₃); Green Lake (A₄); Padre Carvalho street (A₅). Source: authors (2025).

This direct action of DO on non-ionized ammonia (WANG *et al.*, 2023) is a preponderant factor for nitrification to occur: (oxidation and formation of nitrite, nitrate, and organic nitrogen), i.e., there is a direct contribution to the continuity of the organic nitrogen cycle that returns to the environment. This importance of DO for nitrification is due to the availability of bacterial actions (*Nitrosomonas*, *Nitrobacter*, aerobic reaction), as well as mitigating the toxic effect of ammonia (HOSSAIN; FAKHRUDDIN; KHAN, 2007).

In water resources management, monitoring the concentration of water is essential when it involves population growth due to the increase in water consumption and the generation of domestic effluents. In a study conducted as a literature review about NH_3 (SILVA JÚNIOR, 2024), it was identified that population growth influences the volume of domestic effluents generated (CARVALHO; FERRAZ, 2007). As a result, the supply of OD tends to decrease due to the decomposition of OM. In Paragominas, in 2010, the population was equivalent to 97,819 inhabitants (IBGE, 2010), in the census conducted in 2022, the population was 105,508 inhabitants (IBGE, 2022).

Also in this municipality, in 2022, 7.044 inhabitants (6.67%) had their residential bathroom connected to the sanitation network. The others are discontinuous with this service, that is, their waste is destined for: holes, ditches, rivers, streams, among others (IBGE, 2022). Therefore, the waste and effluents generated during personal hygiene may be flowing into the two water bodies, especially the Paragominas stream that crosses the urban area of this municipality. How this waste originates free ammonia by decomposition of this OM, one of its origins, is explained.

It was observed in the last two areas A_4 - Green Lake (Figure 11a), the vegetation cover is non-existent, so the solar radiation is more effective, and the temperature rises: from 23.95° C. In A_3 , where there is the presence of marginal tree vegetation (Figure 11b), to 26.75°C, which induces an increase in concentration of NH_3 (WERKNEH; GEBRU, 2023). Another fact: on the A_4 , there are no aquatic plants because this type of vegetation is cleaned daily. In the cause-effect relationship, in A_5 , there is an increase in the concentration of NH_3 . This effect causes greater availability of nitrogen, which is consumed by aquatic vegetation, which allows its dissemination. in this area (Figure 11c) because the absorption of (NH_3) as a source of nitrogen acts

on the proliferation of this vegetation which, due to the marginal vegetation cover, does not dissipate since solar radiation does not enter the water column (Figure 11d).

Figure 11 – a) Green Lake without aquatic plants and marginal cover; b) Camboatã, with marginal cover (left bank) and aquatic plants; c) growth of aquatic vegetation; d) Shading caused by marginal tree vegetation. Igarapé Paragominas, in the homonymous municipality. Pará. Brazil.

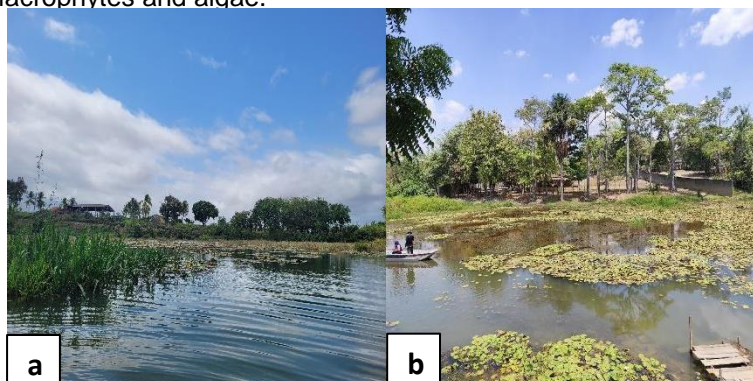


Source: authors (2025).

Degradation of non-ionized or free ammonia in water

One of the ways of degradation of the , is the absorption via aquatic plants and algae. In the data obtained and analyzed, it is verified that in the first three areas, there was an increase in the concentration of this gas ($A_1 = 0.13$ mg/L; $A_2 = 0.26$ mg/L; $A_3 = 0.37$ mg/L). Study conducted on this topic (von SPERLING, 1996) in Lagos correlated land use and occupation with high concentration of algae, siltation, and presence of macrophytes. In A_1 , agricultural sites are still found (Figure 12a), and leisure areas on the banks of the stream, as in A_2 (Figure 12b).

Figure 12 – a) site and macrophytes observed in A_1 ; b) Laser area on the margin (right) on A_2 , also with the presence of macrophytes and algae.



Source: authors (2025).

The pH also causes solubility of this gas. However, in two areas (A_2 ; 6.19; $A_3 = 5.58$), the intermediate values are between low acid and almost neutral. The reference

research for these arguments, based on the data found, was described by the Environmental Company of the State of São Paulo - CETESB (SÃO PAULO, undated). In the last two areas ($A_4 = 0.81$ mg/L; pH = 5.37; A_5 , 1.21 mg/L; pH = 6.53), focusing on the latter, the pH is alkaline. This chemical state of the water tends to increase non-ionized ammonia in the aquatic environment, and, with this, it is perceived that the concentration of DO tends to increase. Study based on the cause-effect relationship of these two variables for water quality (ADAMANTE, 2005; BRAZIL, 2005) It concluded that the DO acts indirectly on the , since its direct action in the aquatic environment occurs on catabolism and anabolism of the organisms of the water environment.

CONCLUSION

The data on free ammonia in the five areas of the urban stretch of the Paragominas stream indicate that there is a stage of pollution in growth, since the parameters DO, pH and temperature, in four of them (A_1 , A_2 , A_3 and A_4), and the increase in the concentration of free ammonia in A_5 , may be flowing into the Uraim River, without any type of treatment. The expanding population growth and the lack of monitoring of basic sanitation in the municipality still do not present equity.

The physical alteration caused in the meander of the Paragominas stream, associated with the expansion of horizontal urbanization, the non-existence of public places as recreation areas and fishing activities, induce communities with economic hypo sufficiency to use the lakes formed in the urban peripheral area of Paragominas, especially children, as observed throughout this research. Fishing, in addition to being sport, is also used as a nutritional provider, since bonfires were observed during the recreational baths practiced there.

As there was previously no data that identified the current state of water quality, it is expected that municipal managers will take advantage of it to develop actions that may not intervene or even improve the areas that are now used for recreation, or even make a planned relocation of floating plants, keeping them under population control and letting them act in favor of water quality. In addition, a reforestation program with native species, on the banks of the Paragominas creek in the urban section will contribute to comply with the guidelines of the Municipal Water Resources Plan of the municipality.

ACKNOWLEDGEMENTS

The first author thanks the University of the State of Pará for granting the doctoral scholarship. The data referring to the concentration of ammonia, a proposition as to the origin, quantity, and changes in the quality of water in the five areas of the urban section, make up Scenarios I and III of the doctoral theses of the first automobile, developed in the Graduate Program in Environmental Sciences (PPGCA) of this higher education institution. To Mr. Ruy Marcos Minto for the many transfers of the aluminum boat, to Mr. Ráulison Dias Pereira (Topography Technician). Finally, we thank the Municipal Department of the Environment of Paragominas (SEMMA) for granting permission for this research, as well as for generating useful data for the conservation of water resources.

REFERENCES

1. ALMEIDA, L. P.; KLUSKA, M.; ALMEIDA, S. M. Z. Caracterização ambiental e análise da água superficial do percurso urbano do rio Xanxerê. **Unoesc & Ciência – ACET**, v. 5, n.º 1, p. 31-38. 2014.
2. ANA. Agência Nacional de Água. **ANA define prioridade para saneamento básico em 2025 e 2026**. 2025. Disponível em: ANA define prioridades para saneamento básico em 2025 e 2026. Acesso em 10 mar. 2025.
3. ANH, N. T. *et al.* Influences of key factors on river water quality in urban and rural areas: A review. **Case Studies in Chemical and Environmental Engineering**, v. 8, 100424, 2023.
4. APHA. American Public Health Association. **Standard methods for the examination of water and wastewater**. 16th ed. Washington: APHA, 1985.
5. ADAMANTE, W. B. **Estresse de alevinos de dourado e mandi sob diferentes densidades e tempos de transportes**. 2005. Dissertação (Mestrado em Aquicultura) – Universidade Federal de Santa Catarina, Florianópolis, 2005.
6. BOYD, C.E.; TUCKER, C.S. **Water quality and pond soil analyses for aquaculture**. Auburn: Auburn University. Alabama Agricultural Experimental Station, 1992.
7. BRASIL. **Resolução CONAMA**, n.º 20, de 18 de janeiro de 1986. Estabelece a classificação das águas doces, salobras e salinas do Território Nacional. Disponível em: <https://www.normasbrasil.com.br/norma/?id=94894>. Acesso em: 14 mar. 2025

8. BRASIL. **Lei n.º 9.433**, de 8 de janeiro de 1997. Institui a Política Nacional de Recursos Hídricos, cria o Sistema Nacional de Gerenciamento de Recursos Hídricos, regulamenta o inciso XIX do art. 21 da Constituição Federal, e altera o art. 1º da Lei nº 8.001, de 13 de março de 1990, que modificou a Lei nº 7.990, de 28 de dezembro de 1989. Disponível em: L9433. Acesso em; 10 mar. 2025.
9. BRASIL. **Resolução CONAMA, n.º 357**, de 17 de março de 2005. Dispõe sobre a classificação dos corpos de água e diretrizes ambientais para o seu enquadramento, bem como estabelece as condições e padrões de lançamento de efluentes, e dá outras providências. Disponível em: conama.mma.gov.br/?option=com_sisconama&task=arquivo.download&id=450. Acesso em 14 mar. 2025.-
10. BRASIL. **Resolução CONAMA , n.º 430**, de 13 de maio de 2011. Dispõe sobre as condições e padrões de lançamento de efluentes, complementa e altera a Resolução n.º 357, de 17 de março de 2005, do Conselho Nacional do Meio Ambiente - CONAMA. Disponível em: [res_conama_430.pdf](#). Acesso em 30 jan. 2025.
11. BRASIL. **Lei n.º 12.651**, de 25 de maio de 2012. Dispõe sobre a proteção da vegetação nativa; altera as Leis nº s 6.938, de 31 de agosto de 1981, 9.393, de 19 de dezembro de 1996, e 11.428, de 22 de dezembro de 2006; revoga as Leis nº s 4.771, de 15 de setembro de 1965, e 7.754, de 14 de abril de 1989, e a Medida Provisória nº 2.166-67, de 24 de agosto de 2001; e dá outras providências. Disponível em: L12651. Acesso em: 12 mar. 2025.
12. CARVALHO, D. S. A.; FERRAZ, P. R. O crescimento populacional e a gestão de resíduos domésticos. 2007. *In*: Fórum Internacional de Resíduos Sólidos. 1, 2007. Rio Grande do Sul. **Anais eletrônicos**. Disponível em: Forum Internacional de Resíduos Sólidos - Anais. Acesso em: 10 mar. 2025.
13. CETESB. Companhia Ambiental do Estado de São Paulo. **Amônia**. Disponível em: Amônia » Mortandade de Peixes. Acesso em: 28 mar.2025
14. CHAGAS, A. P. **A síntese da amônia: alguns aspectos históricos**. Química Nova, v. 30, n.º 1, p. 240-247, 2007.
15. DANTAS, M. S. *et al.* Municipal wastewater discharge standards for ammonia nitrogen in Brazil: technical elements to guide decisions. **Water Science & Technology**, v. 85,n.º 12, 3481, 2022.
16. EDWARDS, T M. Ammonia, and aquatic ecosystems – A review of global sources, biogeochemical cycling, and effects on fish. **Science of the Environment**, n.º 907, 2024.
17. EPA. Environmental Protection Agency. **Ammonia**. 2025.Disponível em: Ammonia | US EPA. Acesso em 10 mar. 2025.
18. ERICSON, R. J. An evaluation of mathematical models for the effects of pH, and temperature on ammonia toxicity to aquatic organisms. **Water Research**,

- n. 19, p. 1047-1058, 1985.
19. FELIX, E. P.; CARDOSO, A. A. Amônia (NH₃) atmosférica: fontes, transformação, sorvedouros e métodos de análise. **Química Nova**, v. 27, n.º 1, p. 123-130, 2004.
 20. FRENEY, J. R.; SIMPSON, J. R. Ammonia volatilization. In: CLARK, F. E.; ROSSWALL, T. (Eds.). *Terrestrial nitrogen cycles*, Estocolmo. **Ecological Bulletin**, n. 33, p. 291-302. 1981.
 21. FREITAS, B. F. *et al.* O uso de operadores como estratégia de busca em revisões de literatura científica. **Brazilian Journal of Implantology and Health Sciences**, v. 5, n.º 3, p. 652-664, 2023.
 22. FUNASA. Fundação Nacional de Saúde. **Manual Prático de análise de água**. 4 ed. Brasília: Funasa, 2013.
 23. GUIMARÃES, G. P.; de MELLO, W. Z. Estimativa do fluxo de amônia na interface ar- mar na baía de Guanabara – estudo preliminar. **Química Nova**, v. 29, n.º 1, p. 54-60. 2006.
 24. HOSSAIN, M.; FAKHRUDDIN, A. N. M.; KHAN, S. I. Impact of raw water ammonia on surface water treatment processes and its removal by nitrification. **Bangladesh Journal of Microbiology**, v. 24, n.º 2, p. 85-89, 2007.
 25. HUANG, J-C; SHANG, C. Air Stripping. In: **Advanced Physicochemical treatment processes**. New Jersey: TOTOWA HUMAN PRESS, 2006, p. 47-78.
 26. IBGE. Instituto Brasileiro de Geografia e Estatística. **Censo 2010**. Disponível em: IBGE. 2010. Acesso em: 01. jan. 2025.
 27. IBGE. Instituto Brasileiro de Geografia e Estatística. **Arranjos populacionais e concentrações urbanas do Brasil**. Rio de Janeiro, 2016.
 28. IBGE. Instituto Brasileiro de Geografia e Estatística. **Censo 2022**. Disponível em: Censo 2022 | IBGE. Acesso em: 01 jan. 2025.
 29. IDM. Instituto de Desenvolvimento Mamirauá. **BioEstat 5.3**. 2023. Disponível em: Instituto de Desenvolvimento Sustentável Mamirauá. Acesso em 12 mar. 2025.
 30. IP, Y. K.; CHEW, S. F.; RANDALL, D. J. Ammonia toxicity, tolerance, and excretion. **Fish Physiology**, v. 20, p. 109-148, 2001.
 31. IVAN, I. *et al.* Physicochemical water parameters – limiting factors on the rainbow trout growth recirculating aquaculture systems. **Scientific Papers. Series D. Animal Science**, v. 67, n.º 2, 2024.
 32. LIANG, Y. *et al.* Monitoring water quality Parameters in urban rivers using

- multisource data and machine learning approach. **Journal of Hydrology**, v. 648, 2025.
33. LIMA, R. G. *et al.* Concentrações de amônio na água da chuva e estimativa de emissão de amônia de rebanhos domésticos de Pinheiro e Viana, baixada Maranhense. **Química Nova**, v. 32, n.º 9, p. 2273-2276. 2009.
 34. LLOYD, S. *et al.* Predicting recreational water quality and public health safety in urban estuaries using Bayesian Networks. **Water Research**, n.º 254, 121319, 2024.
 35. MAZARATI-HIRIART, A. *et al.* Microbiological implications of periurban agriculture and water reuse in Mexico city. **PLOS ONE**, v. 3, n.º 5, e2305, 2008.
 36. MEDHI, K. Integrated assessment of ammonia-nitrogen in water environments and its exposure to ecology and human health. *In*: AHAMAD, A.; ILAHI, S.; SINGH, P. **Contamination of water: health risk assessment and treatment**. Elsevier Inc. 2021. Chapter 14, p. 199-216.
 37. MOEINZADEH, A.; YONG, K. T. ; WITHANA, A. A critical analysis of parameter choices in water quality assessment. **Water Research**, n.º 258, 12177, 2024.
 38. PAST. Palaeontological Statistics. 2024. Disponível em: <https://www.baixesoft.com/download/past>. Acesso em: 26 mar. 2025.
 39. PARÁ. **Perfis econômicos vocacionais dos municípios paraenses**. Belém: Fundação Amazônica de Amparo a Estudos e Pesquisas do Pará – FAPESPA, 2023.
 40. PARAGOMINAS. **Lei n.º 765**, de 26 de julho de 2011. Institui o Código Ambiental Municipal -CAM, contendo a Política e o Sistema Municipal de Meio Ambiente de Paragominas e dá outras providências. Paragominas: Prefeitura Municipal, 2011.
 41. PARAGOMINAS. **Plano Municipal de Saneamento Básico do Município de Paragominas**. Prefeitura Municipal de Paragominas, 2014, p. 47 e 48.
 42. PARAGOMINAS. **Lei n.º 1123**, de 25 de julho de 2023. Institui o Plano Diretor de Desenvolvimento Municipal de Paragominas, PDDMO, para o período 2023-2033 e dá outras providências. Paragominas: Prefeitura Municipal, 2023.
 43. PARAGOMINAS. Secretaria Municipal de Planejamento – SEPLAN. **Divisão Setorial – Bairros – Paragominas – PA**. 2023.
 44. PASSOS, A. L. L. *et al.* Selection of variables in the definition of a water quality index for the Brazilian Federal District. **Ambiente & Água**, v. 14, n.º4, e2385, 2019.
 45. PEREIRA, A. S. *et al.* **Metodologia da Pesquisa Científica**. Santa Maria: UBA/INTTE/UFSM, 2018.
 46. PRODANOV, C. C.; FREITAS, E. C. F. **Metodologia do Trabalho Científico**:

- métodos e técnicas da pesquisa e do trabalho acadêmico. 2 ed. Novo Hamburgo: Feevale, 2013
47. QUEIROZ, J. F.; BOEIRA, R. C. **Boas práticas de manejo (BPMs) para reduzir o acúmulo de amônia em viveiros de aquicultura**. Embrapa: Jaguariúna, 2007. Comunicado Técnico, 44.
 48. dos REIS, J. A. T.; MENDONÇA, A. S. F. Análise técnica dos novos padrões brasileiros par amônia em efluentes e corpos d'água. **Engenharia Sanitária e Ambiental**, v. 14, n.º 3, p. 353-362, 2009.
 49. RODRIGUES, R. S. S. *et al.* Análise dos efeitos de um evento extremo de chuva sobre o escoamento superficial em uma pequena bacia hidrográfica rural amazônica. **Revista Brasileira de Climatologia**, v. 26, p. 348-396, 2020.
 50. SAALIDONG, B. M. *et al.* Examining the dynamics of the relationship between water pH and other water quality parameters in ground and surface water systems. **PLOS ONE**, v. 17, n.º 1, e0262117, 2022.
 51. SANDU, M. *et al.* Non-ionized ammonia pollution level of the mal rivers water in the Central Development Region of the Republic of Moldova. **Present Environment & Sustainable Development**, v 16, n.º 1, p. 251-258, 2022.
 52. SILVA JÚNIOR, A. I. G. Impactos causados pelos lançamentos de efluentes em corpos hídricos. **Revista FT**, v. 28, 2024.
 53. SILVA, A. S. *et al.* Influência do nitrogênio amoniacal na toxicidade dos resíduos sólidos urbanos. *In: Simpósio Ítalo-brasileiro de Engenharia Sanitária e Ambiental*. 12. 2014. Rio Grande do Norte. Disponível em: https://abes-dn.org.br/anais eletronicos/26_Download/TrabalhosCompletosPDF/III-081.pdf. Acesso em 26 mar. 2025.
 54. SILVA, J. M.; SILVA, T. T.; BECKER, H. Otimização das análise de nitrogênio amoniacal em águas de reservatórios. *In: Encontro de Pesquisa de Pós-Graduação*. **Revista Encontros Universitários da UFC**, v.1, n. 1, p. 2206, 2016.
 55. SILVA, R. S. B. *et al.* Avaliação sazonal da qualidade das águas superficiais e subterrâneas na área de influência do lixão de Salinópolis, PA. **Ambiente & Água**, v. 13, n.º 2, e2072, 2018.
 56. SILVA, R. T.; PORTO, M. F. A. Gestão Urbana e gestão das águas: caminhos da integração. **Estudos Avançados**, v. 17, n.º 47, p. 129-145, 2003.
 57. SILVA, S. M. O. *et al.* Proposta de gestão integrada das águas urbanas como estratégia de promoção da segurança hídrica: o caso de Fortaleza. **Engenharia Sanitária e Ambiental**, v. 24, n.º 2, p0.239-250, 2019.
 58. SILVA, T. *et al.* Modelagem e monitoramento do escoamento superficial urbano nas bacias dos córregos Ressaca e Sarandi (Minas Gerais, Brasil). *In: Encontro Nacional de Águas Urbanas*. 10. 2014. São Paulo. *Anais*

eletrônicos. Disponível em:
<https://files.abrhidro.org.br/Eventos/Trabalhos/6/PAP018086.pdf>. Acesso em:
17 mar. 2025.

59. SERAFIN, R. L.; ZABINONI FILHO, E. Effect of combines non-ionized ammonia and dissolved oxygen levels on the survival of Juvenile Dourado, *Salminus brasiliensis* (CUVIER). **Journal of the World Aquaculture Society**, v. 40, n.º 5, p. 695-701, 2009.
60. von SPERLING, M. **Introdução à qualidade das águas e ao tratamento de esgotos**. Belo Horizonte: SESA-UFMG, 1996.
61. TUNDISI, J. G. Recursos Hídricos no futuro: problemas e soluções. **Estudos Avançados**, v. 22, n.º 63, p. 7-16, 2008.
62. UNESCO/WHO/UNEP. Water Quality Assessments. *In*: London : Chapman e Hall, 1992. Cap 3: **The Selection of Water Quality Variables**, p. 51-119.
63. UNESCO. Organização das Nações Unidas para a Educação, Ciência e Cultura. **Relatório Mundial das Nações Unidas sobre o desenvolvimento dos Recursos Hídricos**. Perugia: UNESCO, 2025.
64. WANG, X. *et al.* Water quality criteria of total ammonia nitrogen (TAN) and un-ionized ammonia (NH_3-N) and their ecological risk in the Liao River,, China. **Chemosphere**, v. 243, 125328, 2020.
65. WANG, X. *et al.* Deep-learning-based water quality monitoring and early warning methods: a case study of ammonia nitrogen prediction in rivers. **Electronics**, v. 12, 2023
66. WERKNEH, A. A.; GEBRU, S. B. Development of ecological sanitation approaches for integrated recovery of biogas, nutrients, and clean water from domestic wastewater. **Resources, Environment and Sustainability**, n.º 11, 10095, 2023.
67. WISKICH, A.; RAPSON, T. Economics of emerging ammonia fertilizer production methods -a role for on-farms synthesis? **European Chemical Societies Publishing**, v. 16, e202300565, 2023
68. ZOPPAS, F. M.; BERNARDES, A. M.; MENEGUZZI, A. Parâmetros operacionais na remoção biológica de nitrogênio de águas por nitrificação e desnitrificação simultânea. **Revista Engenharia Sanitária e Ambiental**, v. 21, n.º 1, p. 29-42, 2016.

CONCLUSÕES (GERAIS)

A degradação florestal no município de Paragominas, está relacionada com os ciclos econômicos contribuintes para desenvolvimento dessa localidade. Dentre as ações relacionadas com este fato, tem-se: extrativismo madeireiro, pecuária, agricultura, como aumento da área 1342 ha para 103.164 ha. Tem-se ainda a sojicultura e a expansão urbana, que evoluiu de 1331,5 há para 2026,8 ha, até 2021, o que insere 1,5 km de urbanização às margens do igarapé Paragominas, estas expansões provocaram uma redução equivalente a 207,91 ha, entre 2000 e 2021, na área ocupada pelas águas superficiais nas quais se incluem as do igarapé Paragominas.

As plataformas rodoviárias inseridas na urbanização do município, como a Rodovia Constantino Pereira do Sacramento outrora denominada “Rodovia dos Pioneiros”, alterou a estrutura meândrica do igarapé Paragominas, tanto na largura quanto na profundidade, e na deposição de sedimentos no substrato de fundo, além de induzir a uma nova formação lagunar como ocorreu nas cinco áreas analisadas e que compõem o trecho urbano deste igarapé. Outra influência advinda do desmatamento, pode estar associada a redução nas taxas de precipitação anual no município, o que poderá comprometer o abastecimento de água para os municípios futuramente.

A criação de assentamentos localizados na área da microbacia hidrográfica do município é outro fator de alterações de impactos antropogênicos que alteram as condições ambientais, já que há seis deles presentes nesta área. Isto gera águas cinzas, além dos dejetos humanos e da bovinocultura que desaguam neste igarapé devido a declividade do relevo até a Rodovia Constantino Pereira do Sacramento. Tais fatos foram mensurados com a aplicação do Protocolo de Avaliação Rápida do Habitat, para o cálculo do Índice de Integridade do Habitat – IIH, que envolveu a urbanização, os impactos antrópicos e as atuais condições ambientais a partir do uso e ocupação do solo e das alterações marginais ocorridas no igarapé Paragominas.

Dos sete parâmetros analisados e mensurados para os impactos antrópicos, bem como para as condições ambientais, na A₁ – Rodovia Constantino Pereira do Sacramento, o valor para o IIH, indicou que ela está impactada em quase 50%, ou seja, 47,2%. Embora a urbanização nesta área, não seja, tão elevada, o que mais contribuiu para esta classificação foi a implementação da plataforma rodoviária pois a inserção de aterros e a não construção de calhas de corte (*cutting gutter*) de forma correta acarretou grande deposição de sedimentos residuais do nivelamento desta rodovia e provocou a modificação do sedimento de fundo deste lago. Além da substituição por vegetação secundária arbustiva e herbáceas.

Para A₂ – Av. Selecta, antiga área de serrarias, dista da A₁, a 518 m, em linha reta. Nela, a margem direita, apresenta localidades recreacionais denominadas “sítios”, onde se percebe a total retirada da mata ciliar, no sentido montante-jusante. Já a margem esquerda, no mesmo sentido, há presença de aterramento e elevação de um talude. Além da construção de áreas de recreação e unidades arquitetônicas, e assentamento da plataforma rodoviária de acesso ao residencial. Bem como há o desague de bueiros para lançamento de efluentes domésticos.

Percebeu-se também que, a pesca artesanal e a balneabilidade são frequentes nesta área pelas famílias que habitam o Conjunto Residencial Selecta. No sentido da saída deste residencial, parte do corpo hídrico, já está aterrada, e ofertada para vendas, sob a forma de lotes. Observa-se também a existência de bueiros que desaguam no igarapé. Tudo isto diminuiu mais ainda a calha central dele, provocou

maiores desvios do curso d'água, e a contínua presença de “quintais” para lazer. Todos estas alterações ambientais provocaram uma classificação como “altamente impactada” (IIH = 28.6%). Isto comprova que a urbanização quando não planejada adequadamente, interfere no ambiente como um todo.

Na A₃ - Confluência da rua Gregório Santos Araújo com PA 125, a plataforma rodoviária está a 15 m da lâmina d'água, pela margem direita do lago onde a presença de material alóctone é visível. A derrocada da mata ciliar, também. Na margem direita, há unidades residenciais cujos “quintais” são áreas marginais ao igarapé Paragominas com uma declividade ($\approx 10^\circ$). Em períodos chuvosos, o escoamento superficial carrega partículas para o interior do igarapé em tela. Além disto, a “limpeza” e a dragagem, quando efetuadas, os sedimentos de fundo, bem como a vegetação aquática são depositados à margem do igarapé. De forma mais escassa que A₂, a área é utilizada para balneabilidade. Todos estes aspectos avaliados permitiram classificar este local como “altamente impactado” (IIH = 7,8).

Na A₄ – Lago Verde, verificou-se que a deformidade do meandro foi muito mais intensa, bem como o aterramento dele. Nele, desaguam 16 pontos de efluentes (bueiros), com cotas hipsométricas elevadas: 124 a 148, na parte mais elevada, até 72 a 81 m, já no lago. O histórico dela indica o uso como um “lixão a céu aberto”. Todas estas ações comprometeram ainda mais os impactos antropogênicos que tiveram o maior valor (10). Isto também comprometeu a condição ambiental da área porque cinco dos sete itens analisados obtiveram nota zero. Com isto, o valor para o IIH, foi o mais baixo de todos (4.2). Notou-se que a transformação paisagística neste local foi incrementada, todavia, ambientalmente, elevou-se a perda de inúmeras funções ecossistêmicas, especialmente a provisão e a regulação térmica.

Na A₅ – Rua Padre Carvalho, o fluxo da massa de água advinda das áreas anteriores, adentra a calha central desta área que é apresentada um elo inter margens: uma ponte de concreto com tráfego de fluxo duplo. Na parte anterior a ponte (100m) não há residências marginais, porém, a 10 m, já se observa os quintais com algumas latrinas sobre a lâmina de água, com presença de girais na margem direita no sentido montante → jusante. Nesta área, antes e após a ponte, a vegetação aquática é preponderante. Dentre elas, a mais frequente é o capim do gênero *Brachiaria* que alguns habitantes desta área fazem a retirada e vendem aos criadores de equinos. Todos estes fatos contribuíram, de uma forma indireta, já que ela é receptora de impactos oriundos das áreas anteriores, para que o valor do IIH (10,4) induziram à classificação como “altamente impactada”.

Todos os impactos antrópicos que alteraram as condições ambientais, atuaram sobre a qualidade da água. No contexto da temperatura da água, a perda da mata ciliar ou a substituição por vegetação de médio e pequeno porte tem influência direta sobre as águas superficiais porque a tendência de elevação desta variável foi mais acentuada na A₄ – Lago Verde (37.8°C), quando comparado com as demais áreas cuja tendência de elevação oscilou entre 31.4°C a 32.6°C. Como esta variável atua sobre o OD, o menor teor deste gás, foi aferido neste local [0.9 mg/L]. Isto afetou a disseminação de peixes que outrora existiam neste local.

Neste local, a proliferação de algas é imenso, já que elas tendem a sufocar a superfície da água, evidente a radiação solar, com isto, falecem e afundam. Quando isto acontece, há uma maior consumo de oxigênio dissolvido, devido a decomposição. Por isto, os órgãos da gestão municipal promovem diariamente a remoção destas algas neste local, mas não determinam uma solução quanto ao descarte de efluentes domésticos nesta área. Nestes efluentes há presença de substâncias nitrogenadas que deverão ser decompostas para gerar nitratos e nitritos, frequente, o que

incrementa o consumo de OD, por bactérias decompositoras de MO, bem como a amônia não ionizada ou livre (0.81 mg/L).

Outro fator que chamou a atenção, foi a acidez na A₄ (pH = 0.9), embora, para as águas amazônicas ($4,5 \leq \text{pH} \leq 5,5$), todas as outras também estão ácidas (1.2 a 2.3). Isto pode explicar a retenção mínima ocorrida na A₄ para o OD (0.9 mg/L), pois em águas ácidas, uma das funções atreladas à esta variável paramétrica hídrica é a atuação sobre as reações químicas no meio aquático, tanto as consumidoras quanto as produtoras. O que chamou a atenção captação, por carro pipa da água na A₃ – Confluência da Rua Gregório Santos Araújo, bairro Camboatã, que dista 12 m da A₄, para irrigação dos jardins urbanos. Ainda acidez elevada não seja recomendada para esta ação, já que as águas que adentram o Lago Verde, sejam aquelas denominadas como “cinzas”.

Em A₁ – Rodovia Constantino Pereira do Sacramento; A₂ – Avenida Selecta, e A₃, a presença de uma ilha de aninga (*Montrichardia linifera*) uma das retentoras de sedimentos em igarapés quando o desmatamento marginal gera a inserção de sedimentos para o interior das águas superficiais. Ainda, a maior parte deles, ficou foram retidos nos rizomas destes vegetais (A₁ = 256.4 mg/L; A₂ = 248,9 mg/L; A₃ = 236,2 mg/L). Já na A₄ onde elas não se fazem presentes, o quantitativo, em média, atingiu 357 mg/L. Isto indica que os sedimentos adicionados pela perda da mata ciliar para implantação de áreas urbanizadas influenciam diretamente na qualidade das águas superficiais, que podem ser mensurados não só pelos parâmetros físico-químicos, mas o uso da vegetação aquática é um bom parâmetro para tal.

No caso da CE, a indicação de fator polutivo por atividades urbanas foi constatado na A₃, já que as margens apresentaram residências marginais, ausência de vegetação na margem direita, sentido montante → jusante. Estes dois fatores provocaram a elevação do valor da média para CE (390 µs/cm), quando comparado com outras áreas. Nestas, o valor médio oscilou entre 146,7 µs/cm e 330,2 µs/cm. É possível que, o uso pretérito desta área por serrarias e pastagens nas áreas antecedentes, ainda tenha resquícios de efluentes estagnados, devido as áreas de remanso que ocorre nesta área, e a presença de macrófitas aquáticas em grande quantidade.

Enfim, pode-se perceber que nas cinco áreas analisadas no trecho urbano do Igarapé Paragominas. Em termos analíticos por área, a A₁, é a menos impactada porque o processo de urbanização ainda não é preponderante. Ainda, o tráfego na PA 125, é intenso para veículos de grande porte que provocam inserção de partículas para o interior deste igarapé, interferindo na qualidade da água. A balneabilidade ali praticada prova deposição de resíduos sólidos e dejetos humanos, mas a pesca artesanal ainda é praticada pelos frequentadores.

Na A₂, segmento que recebe o fluxo da massa de água deslocada por declividade quase inexistente (-0,3°), além da perda de vegetação marginal, construção de taludes, plataformas rodoviárias para acesso em residencial, provocaram assoreamento e conseqüente perda da profundidade. Por isto, durante o período chuvoso, tem-se a ocorrência de enchentes e inundações na pista de acesso. Além disto, os efluentes domésticos desta localidade desaguam diretamente no canal do igarapé através de bueiros existentes na margem esquerda no sentido montante → jusante. A geração desta MO tem provocado constante crescimento de macrófitas aquáticas com deposição de resíduos sólidos domésticos especialmente plásticos.

Na perspectiva polutiva apenas por avaliação das diretrizes paramétricas da Resolução CONAMA 357/2005, os trechos então apresentando poluição em evolução que, se não forem corrigidas as anormalidades aqui relatadas, a tendência é a

elevação desta poluição. Por isto, os dados aqui contidos podem colaborar com as autoridades ambientais locais quanto a elaboração de ações de curto médio e longo prazo, para comparações futuras de outras pesquisas e monitoramentos na qualidade da água.



Universidade do Estado do Pará
Centro de Ciências Naturais e Tecnologia
Programa de Pós-Graduação em Ciências Ambientais
Doutorado Acadêmico
Tv. Enéas Pinheiro, 2626, Marco, Belém-PA, CEP: 66095-
100

