CONCILIUM, Vol. 23, Nº 2, 2023
DOI: 10.53660/CLM-1017-23C37
ISSN: 0010-5236

Riparian vegetation, permanent protection area and water quality in the amazon region, Pará state

Vegetação ribeirinha, zona de proteção permanente e qualidade da água na região amazônica, estado do pará

Received: 2023-02-10 | Accepted: 2023-03-20 | Published: 2023-04-01

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ABSTRACT

Riparian vegetation or riparian forest maintains a direct relationship with water resources because it has several functions, among them, the maintenance of water quality. The objective of this research was to analyze the gaps between the permanent protection area, the riparian vegetation or riparian forest and water quality, contained in publications between 2012 and 2021, for the municipality of Paragominas, Paraense Amazon. The methodology used was inductive of quantitative and qualitative scope, and observational nature. The secondary data were obtained in electronic links, of free access, involved with the themes of this research. The literature selection occurred with the application of three selective descriptors: permanent protection area, riparian forest, and water resources, associated with water quality. The data obtained and analyzed indicated that, of the four literatures selected, the gaps found were related to: lack of analysis of water quality (n = 2; 50%); lack of suggestions for the problem encountered (n = 1; 25%). Therefore, research on vegetation/riparian forests is still analyzed without the context of environmental integration in terms of the ecosystem and environmental services provided both by these vegetations and for water bodies.

Keywords: Conservation of marginal vegetation; Water scarcity; Water quality.

RESUMO

A vegetação ribeirinha ou mata ciliar mantém uma relação direta com os recursos hídricos porque tem várias funções, entre elas, a manutenção da qualidade da água. O objective desta investigação foi analisar as lacunas entre a área de proteção permanente, a vegetação ribeirinha ou mata ciliar e a qualidade da água, contidas em publicações entre 2012 e 2021, para o município de Paragominas, Amazónia paraense. A metodologia utilizada foi indutiva de âmbito quantitativo e qualitativo, e de natureza observacional. Os dados secundários foram obtidos em ligações electrónicas, de livre acesso, envolvidas com os temas desta investigação. A seleção bibliográfica ocorreu com a aplicação de três descritores seletivos: zona de proteção permanente, mata ciliar, e recursos hídricos, associados à qualidade da água. Os dados obtidos e analisados indicaram que, das quatro literaturas selecionadas, as lacunas encontradas estavam relacionadas com: falta

de análise da qualidade da água (n = 2; 50%); falta de sugestões para o problema encontrado (n = 1; 25%). Por conseguinte, a investigação sobre vegetação/florestas ripícolas é ainda analisada sem o contexto da integração ambiental em termos do ecossistema e dos serviços ambientais prestados tanto por estas vegetações como pelas massas de água.

Palavras-chave: Conservação da vegetação marginal; Escassez de água; Qualidade da água.

INTRODUCTION

The loss of natural riparian or marginal riparian vegetation in springs and watercourses, perennial or intermittent, whether rivers, lakes, ponds, hybrid aquatic environments such as dams, causes environmental problems such as the physical, chemical, and biological imbalance of watersheds. There is also a loss of habitat and biodiversity, accentuation of soil erosion, loss of indigenous plant species, in addition to contributing to climate imbalance. Therefore, the challenge of maintaining them is quite difficult. (CASTRO et al., 2017; PATIÑO, 2020; SAVIATO et al., 2021).

Riparian or riparian vegetation is a “forest plug” adjacent to lotic water bodies, such as a stream, or lentic water bodies, such as a lake, or wetland. These buffers are composed of tree and shrub vegetation, perennial plants, components of the different surrounding landscapes, and offer environmental benefits such as filtering nutrients, pesticides, organic residues, surface runoff, stability against soil erosion, shading, shelter, and nutrition for fish. and conservation of water quality (LACERDA et al., 2020; MacFARLAND et al., 2017).

In the legal scope, all these functions are lost when these areas are deforested, as they are described in article 3, item II, of Law No. 12,651 (BRASIL, 2012), and this also applies to the so-called “artificial reservoirs” such as hydroelectric dams, as described in article 4, item III, of that Law. However, deletion is permitted, pursuant to the wording of article 8, provided that it is for purposes of public utility, social interest, and provided that it causes low impact. In addition, it must not exceed 5% of this Permanent Protection Area, as established by the Resolution of the National Council for the Environment - CONAMA, No. 369. However, a judicial inspection is required (BRASIL, 2006; SILVA et al., 2020).

In Chapter II of this Law, it is defined that Permanent Protection Areas, whose acronym is APP, are areas covered or not by native vegetation, and have the environmental function of preserving water resources, the landscape, and geological stability, biodiversity, the gene flow of fauna and flora, protect the soil and ensure the well-being of human populations (BRASIL, 2012) In this same chapter, it is established

that owners (individuals/legal entities) or holders of titles, or even occupants, of areas with APP presence, are obliged to keep them (MIRANDA et al., 2020).

The economic and urban development of municipalities can cause serious environmental impacts, such as the suppression of riparian vegetation in marginal areas. Where before there was riparian vegetation, pastures, cattle watering, construction of hydro ports, agricultural crops, among others (ISSUI et al., 2020). The new use causes changes in the characteristics of the hydrographic basins: loss of depth of the bed of the water body; change the local topography and water quality, decrease in carbon sequestration in urban areas, especially in places where the vehicle fleet of motor vehicles and agricultural machinery tends to grow (LIRA et al., 2020; PEREIRA et al., 2022).

Such actions are practiced because the majority of the population is unaware of the biological, ecological, hydrological, and socioeconomic functions performed by riparian forests for the maintenance of biodiversity. The lack of this information, or limited knowledge about them, induce individuals to the inappropriate use of marginal soils and the suppression of the vegetation cover that exists in them (GOMES; VIEIRA, 2018). When the occupation of marginal land is carried out by urban expansion, after the removal of riparian vegetation, residences are inserted, which are subjected to an environmental vulnerability such as floods and inundations. (PARREIRA et al., 2021).

The aforementioned facts have the potential to change the water quality in terms of physical, chemical, and biological parameters, regardless of the economic activity that replaced the riparian vegetation. In the case of agricultural crops, the indiscriminate use of defensives or pesticides, whether herbicides, fungicides, or insecticides (FERREIRA et al., 2019), can result in chemical compounds, organophosphates (synthetic organics) that can lead to the bioaccumulation of phosphorus, which is easily carried into the water body. This can increase the bioavailability of this chemical element and even sedimentation (REGO, 2022).

In the municipalities of the Paraense Amazon, where agriculture and livestock are the economic bases (CRUZ et al., 2022), as in Paragominas, in southeastern Pará. The suppression of riparian vegetation and marginal land use has influenced the water infiltration rate, in addition to changing the physical-chemical conditions and interfering with aquatic communities such as macrophytes (GALVÃO, 2020; LIMA, 2019). Such changes are not restricted to the tributaries of the Uraim River, but extend to the Capim River, of which the first is a tributary that, in hydro-agricultural areas, compromises the

distribution of rainfall and, consequently, the management of the watershed (CONCEIÇÃO, 2020; LIMA, 2021).

In relation to the management of the hydrographic basin of this river in this municipality, the Legislative Power created, in 2006, Municipal Law No. 598. The objective was to create the Environmental Protection Area - APA, of the Uraim river, regulate the use and occupation of the soil on the banks of this body of water, based on the 1965 Forest Code, Federal Law No. 4775, for establishing the limits of the marginal strip, and CONAMA Resolution No. 303 (BRASIL, 2002). This was one of the instruments for regulating and protecting the native vegetation or riparian forest of the genuinely Paragominas waterbody.

In this context, article 3, item II of this municipal law deals with the conservation of native forest, in addition to the recovery process of riparian forests, since deforestation had occurred since 1968, when the pioneers arrived. In chapter 4, article 4, the Urbanized Conservation Zone was established (item II); the zone of agricultural use and native forest (item III). In the latter, the objective was: to guarantee the conservation of water resources and the public supply of drinking water, whose collection, treatment, quality control and distribution are activities carried out by Paragominas Sanitation Company - SANEPAR (PARAGOMINAS, 2006).

All the issues identified in research carried out on the protection of watercourses and the environmental condition of the riparian forest, as well as the conservation and/or degradation of riparian vegetation and water bodies, justified the relevance of this research. These arguments contributed to the Preparation of the objective, which will answer the following question: what is the current status and gaps contained in scientific research on riparian vegetation or riparian forest, as a Permanent Protection Area and water quality?

METHODOLOGY

The methodological application of this research followed the path described by Rodrigues et al. (2019) and Santos et al. (2021): systematic review (SR), with quantitative and qualitative coverage. In the case of SR, it allows an analysis whose genesis is associated with the survey of academic production in pre-defined sources for selection, evaluation, and synthesis of relevant evidence. In this research, the themes were: riparian vegetation, Environmental Protection Area, and water quality.

The quantitative approach was used to build the profile of these subjects using numerical data. Finally, the qualitative one, which after obtaining data on the subjects' impressions, that is, how is the quality of the studies in relation to the triad of subjects analyzed.

OBTAINING SECONDARY DATA

Obtaining these data was carried out by accessing free access digital platforms such as Google Scholar, *Science Electronic Library Online* (SciELO). *Web of Science*, among others. For a better application of the methodology, four steps were used that allowed a better systematization of the research (Chart 1).

Chart 1. Five steps used to obtain secondary data.

Steps	Action	Characteristics
1	Establishment of the time frame	- 2012 to 2022. This cut is justified by the 10 years of enactment and publication of the new Forestry Code, Law nº 12651/2012. Emphasis was given to the last five years (2018 – 2022), to seek more recent information. — The following federal laws were excluded from this timeframe: National Water Resources Policy, Law No. 9.443; CONAMA Resolution No. 357, 396, 398 and 430, and Decree No. 8972 (BRASIL, 1997; 2005; 2006; 2008; 2011; 2017); state and municipal
2	Academic literary research	- Congress electronic portals, Google Scholar, Journal Portal of the Coordination for the Improvement of Higher Education Personnel (CAPES), Scientific Electronic Library Online (SciELO), Web of Science, among others.
3	Selection	**3.1** Topics related to riparian vegetation or riparian forest; APP and water quality.
		3.2 Publications typified as: articles, dissertations, and theses (with approval and signatures of the evaluating board).
		3.3 Descriptors, with search string: riparian vegetation or riparian forest; riparian vegetation and APP more water quality; APP and water quality.
		3.4 The selected literature must identify the municipality of Paragominas as the place where it occurs.
4	Exclusion	**4.1** It occurred when the relationship between the selective descriptors with water quality and the research location was not evident
	Inclusion	**4.2** It occurred from the identification and relationship between the selective descriptors and water quality, as well as the identification of the research site: Paragominas. In addition to the use and occupation of the soil, and suggestions for mitigation on the physical-chemical changes identified in the selected literature.

Preparation: authors (2023).

The application of the descriptors associated with the Boolean operators was conducted in accordance with the synthesis presented by the Library of the University of Campinas (UNICAMP, 2000).

RESULTS

Selection

The selection of academic literature for this review was selected without (Timeless) and with a time frame (2012 – 2022). In the first case, studies on APP (Table 1), when compared with associated riparian forest and riparian vegetation, and as indicators of some type of alteration in the physical-chemical conditions of water quality, were more prevalent (n = 149,000). In the second case, in the Amazon region of Pará, the number was slightly higher (n = 20,000; 13.4%) than in the North region of Brazil (n = 17,000; 11.4%).

CONCILIUM, Vol. 23, Nº 2, 2023
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ISSN: 0010-5236

Table 1. Quantitative of selected literatures after the application of the three associated selective descriptors in the Brazilian territory, northern region, Para state and Paragominas, with a time frame between 2012 and 2022.

	BRAZIL			NORTHER REGION			PARA STATE			PARAGOMINAS		
	A	T		A	T		A	T		A	T	
ASSOCIATED DESCRIPTORS	-	E	I	--	E	I	--	E	I	--	E	I
Environmental Protection Area and Water Quality more BR	149.000	4.890	3.950	17.000	--	17.100	--	E	I	2.440	770	1.670
Riparian Forest and Water Quality more BR.	29.600	4.000	15.600	15.900	600	15.300	17,700	3,600	14,100	447	131	316
Riparian Vegetation and Water Quality more BR	12.500	3.010	6.530	8.070	2.130	5.760	7,500	5,130	2,370	502	145	357
Totais	**191.100**	**11.900**	**26.080**	**40.970**	**2.730**	**38.160**	2,550	1,660	890	**3.389**	**1.046**	**2.343**

Legends: A. Timelessness; T. Temporality. E. Exclusion; I. Inclusion. Prepared by the authors (2023).

For the five-year period 2018 - 2022, the amount was extracted from the total selected from the pre-established time frame (2012-2022). The average values of publications of the three associations that occurred in the municipality of Paragominas evolved. However, the number of studies on "riparian vegetation and water quality in the Paraense Amazon," in the five-year period decreased, when compared to the other two associations (Table 2).

Table 2. Quantitative of academic literature selected for the established five-year period (2018-2022), in the context of the Para state and the municipality of Paragominas, Pará.

	PARA STATE	PARAGOMINAS
ASSOCIATED DESCRIPTORS	2018-2022	2018-2022
Environmental Protection Area and Water Quality more BR.	13.100	187
Riparian Forest and Water Quality more BR.	2.200	163
Vegetation and Water Quality more BR	978	96
Totais	**16.278**	**446**
$\bar{x} \pm \sigma$	**5.426±6,674**	**149±47**

Prepared by the authors (2023).

The selection of literature resulting from studies involving associations between selective descriptors and water quality, which took place in Paragominas, indicated that, between 2012 and 2022, only a small part (n = 1,151; 4.8%%) of the total research carried out and published in the context of the Paraense Amazon (n = 23,800; 7,933±7,204), showed such associations. For the full readings on the associated descriptors used and the municipality of Paragominas, a last observation was made regarding the use and occupation of the soil and the suggestions described in these studies for the solution of the identified problems. As a result, only four publications met the objective of this research (Chart 2).

Chart 2. Literature produced in Paragominas that met the final requirement for analysis.

Title	Publication Year	Goal	Conclusion	Suggestions
Recovery initiative of the riparian forest on the banks of the Uraim River in the municipality of Paragomnas-PA.	Borges et al., 2018	Recover the riparian forest from the Uraim Colony.	The entire length of the Uraim river riparian forest is degraded.	Use of commercially valuable plants (e.g., Euterpe oleracea)
Physical chemical characteristics of water from springs in areas of different land uses and APP, in the municipality of Paragominas (PA)	Souza et al., 2018.	Evaluate the quality of springs	Quality of spring water susceptible to contamination in the absence of APP.	There was none.
Environmental impacts arising from urbanization on the banks of the Prainha river, Paragominas, PA.	Cruz et al., 2019.	It studies the changes resulting from urban growth, in the biotic and physical aspects in the adjacent area of the Prainha river, Paragominas.	Urbanization has altered the biotic and physical environment due to the irregular occupation of the banks of the Prainha River. The removal of the riparian forest increased the levels of luminosity and water Temperature..	Recover the riparian forest with native vegetation. expropriation at the Zea mays site. implement: drainage system; sewage treatment station.
Influence of land use on the water infiltration rate in the watershed of Igarapés 54 and 7, Paragominas, Pará.	Galvão, 2020	Changes in infiltration rates in areas of riparian forest, pasture and agriculture.	Infiltration rates depend on the soil where they occur: riparian forests (low value, clayey soil), pastures (they are variable); agriculture is close to stability (60')	Use of double cylinder infiltrometers, improved estimation of the infiltration rate, in addition to other techniques such as Philip-Dunne and Guelph permeameters, and

				Strait infiltrometer.

Prepared by the authors (2023).

DISCUSSION

Riparian vegetation or riparian forest

The riparian vegetation or riparian forest or riparian vegetation is a strip of vegetation that grows on the banks of rivers, streams, and lakes, especially in the Paraense Amazon. In the context of this Amazon, the municipality of Paragominas has a hydrographic microbasin with the total area of the municipality, equivalent to 21.75%, that is, 4.9 km2. In this locality, Borges et al. (2018), carried out a study on the loss of this marginal vegetation cover, in the settlement called Colonia do Uraim". They concluded that there was a loss of riparian forest, from the implementation of economic activities in marginal soils: livestock and agricultural irrigation. The most effective consequence was the loss of water recharge capacity of the Uraim River, to the volume of the flow that existed before.

Another very important identification carried out in this research is related to the native vegetation that was found in a small marginal area where the "natural forest" predominates, where economic species such as *Clitoria fairchildiana*, and *Bauhina rutilans* Spruce ex Benth. whose vernacular names are haystack and tortoise ladder, respectively. The proposed mitigation follows the line of income generation, therefore, reforestation with *Syzygium cumini* L. Family Myrtaceae (RIBEIRO et al., 2010), *Virola surinamensis* (Rol. ex Rottb.) Warb. Myristacaceae family (CRUZ; BARROS, 2016), and *Veronica Oficinallis* L., Plantagínaceae family (https://jb.utad.pt/especie/Veronica_officinalis).

Another function performed by the riparian vegetation/riparian forest is performed by the roots embedded in the marginal soil: to contribute to the infiltration of rainwater and, with this, promote the recharge of the water table from the surface runoff, as well as to avoid the erodibility of the river. soil, which may induce a loss of depth in the water body, called "silting." In Paragominas, igarapés 54 and 7, two tributaries on the right and left banks, respectively, in the upstream downstream direction, have already been studied on these functions.

In the case of this study, Galvão (2020) identified that there are areas where the riparian forest is present, and areas where it has already been replaced by pastures and agriculture. In the first case, the authors listed clayey soils containing this type of forest, the infiltration rate having a low value; already in areas of pastures, it was identified that

there is a difficulty in retaining soil moisture and, finally in the area of agriculture, infiltration stabilized in 60 minutes. This may have occurred due to the irrigation process used.

As for the process of replacing native vegetation described in Law No. 12,652 (BRASIL, 2012), this has already been identified on the right bank of the Paragominas/Prainha river, in Paragominas. Cruz et al. (2019), when analyzing the type of marginal vegetation on Street Bujaru, Allotment I, subdivision neighborhood, in this municipality, verified the presence of "elephant grass, of the species Pennisetum purpureum Schum., Poaceae family (XAVIER et al., 1995)". The adaptation of this forage plant is due to the temperature (26°C) and the precipitation rate (800 mm/year) that occur in this municipality. However, it is not native vegetation, nor does it act in the conservation of water quality since there was the presence of pollutants due to the presence of herbs and macrophytes.

In addition, the use of another type of vegetation other than the native one is contrary to Article 3, item VI, of the National Plan for the Recovery of Native Vegetation, Decree No. 8,972 (BRASIL, 2017). In it, recovery can be conducted with the application of an agroforestry system, reforestation, natural regeneration of vegetation, rehabilitation, and ecological restoration. In the state of Pará, recovery guidelines are based on the Pará Forestry Program (BESSA, 2019), and on Environmental Regularization, Decree No. 1.379 (PARÁ, 2015).

Water quality

For the analysis of water quality in the Uraim River, the guidelines for Class 2 should be taken as a basis, in accordance with the specifications contained in CONAMA Resolution No. 357 (BRASIL, 2005). In this document, parameters are described that serve as a basis for establishing the "quality of raw water for public supply", and this created the so-called "Index of Quality of Raw Water for Public Supply", whose acronym is IAP and has three evaluation groups (Table two).

Chart 2. The three component groups of the IQA.

Parameter groups	Components / description
IQA	Water temperature, pH, dissolved oxygen, biochemical oxygen demand, fecal coliforms, total nitrogen, total phosphorus, total residue, and turbidity.
Presence of toxic substances[1]	Mutagenicity test, potential for Trihalometham, cadmium, lead, total chromium, mercury, and nickel formations
Organoleptic qualities[2]	Phenols, Iron, Manganese, Aluminum, Copper, and Zinc.

[1+2] They make up the so-called “Index of Toxic and Organoleptic Substances (ISTO). Prepared from data collected at:http://pnqa.ana.gov.br/indicadores-indice-qualidade-bruta.aspx.

The Uraim River, according to SANEPAR, serves as a “spring” for capturing raw water which, after treatment, is distributed in a network by this company to the local community. This capture is conducted in a stretch located in the transition between rural and urban areas. Currently, 47% of the population of Paragominas is served by this company, according to a survey carried out in that location by Cruz et al. (2018). Still according to this author, the current 180L/s of the flow of the water body on screen, meets human needs (70 to 120 L/inhab/day), animals in cattle raising (50L/animal/day) in addition to poultry (0.4/L/bird/day).

Due to all these aspects regarding consumption, the concern with water quality must start from the place where, due to negative capillary pressure, the water comes from the groundwater: the “water holes” or “springs”. The greater the conservation of vegetation cover in these places and throughout the marginal extension of water bodies, the better the water quality. In Paragominas, the concern with these areas is contained in the research conducted by Souza et al. (2018) in this location.

These authors call attention to the degrading anthropic actions of these springs, of the APPs, and the insertion of agriculture, pastures, forestry and architectural units and the drainage of domestic effluents. Evidence of the negative alterations that occurred in the physical-chemical parameters of the waters, such as the hydrogen potential (pH), dissolved oxygen (OD), electrical conductivity (EC), turbidity and temperature. In view of these changes, they concluded that the absence of vegetation cover caused greater susceptibility to contaminants in this spring.

CONCLUSION

The identified gaps are associated with:

1) Lack of knowledge on the part of users regarding the importance of conservation and maintenance of riparian vegetation or riparian forest. Their environmental sensitivity has not yet been the object of studies, as well as the degree of knowledge regarding the ecosystemic and environmental functions that this vegetation performs, and what are the advantages that the communities that use these water bodies have, when working towards the maintenance of these vegetations.

2) Municipal Law No. 598/06 contains the creation of an environmental protection area and not a permanent protection area which, in the new Water Code, explains the function of the APP, as an area that is or is not native vegetation is present, it has the function of preserving water resources.

3) The lack of training of the community of farmers regarding the conservation of the riparian forest, and the quality of the water they use for irrigation of the agricultural crops they produce. Even if another type of vegetation occurs, it may not offer the protection for maintaining water quality as occurs with native vegetation. As there are plantations of an economic nature, it was evident that this factor is still preponderant over the maintenance determined by the 2012 Forest Code.

4) There is no analytical effectiveness on the waters of the Paragominas igarapé, affluent on the right bank, upstream downstream direction, whose most of its extension is intersected by the urban area, therefore, it has become a receiving body of domestic effluents and rainwater, as well as there are no studies indicating whether or not the dilution or formation of recalcitrant compounds occurs within this body of water.

Therefore, the data contained here may be the object of further research, so that more research of an associative nature can be carried out so that the municipal water supply has a more integrated management with its tributaries and can increase public supply with better quality of the water they capture and distribute to the local community.

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