Assessment and Perceptions of the Environmental Quality of the Urban and Suburban Wetlands of Leticia (Amazonas, Colombia)

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INTRODUCTION

The Amazon River Basin, the most extensive and main *hotspot* of diversity on the planet (Bertzky et al. 2013), hosts the largest terrestrial biodiversity of plants and animals. However, it is not only relevant for its ecological attributes, but also in social and cultural dynamics and, in particular, as a reference in the various responses to global change (Betts et al. 2008; Vargas et al. 2019). This had led several countries (including Colombia) to consider the Amazon Basin as a *subject of law*, in which the State is primarily responsible for its conservation and protection (Macías 2018; Trujillo 2013). On the other hand, the Amazon region exhibits all the ecological characteristics associated with global aquatic species (Albert et al. 2011). For example, phylogenetic and biogeographic patterns, in the case of Neotropical freshwater fishes, suggest that in this region most speciation occurred along geographic rather than ecological events (Albert and Crampton 2010). Likewise, based on vegetation types in the Colombian Amazon Basin, there is a high ecosystem richness (Rudas 2009). In the case of aquatic ecosystems, the region registers 16 out of the 89 types of wetlands (Ricaurte et al. 2019). It is worth emphasizing that Amazonian aquatic ecosystems have an evolutionary history that exceeds 23 million years (Hoorn et al. 2010). In recent times, since the arrival of the first humans some 12,000 years ago (Morcote et al. 2017), life and culture have been closely linked to these ecosystems (Santos et al. 2013).

Wetlands, due to their geological, biogeographical, and ecological history (McInnes 2011; Horwitz and Finlayson 2011) are one of the most productive and diverse ecosystems in the world (Gopal and Junk 2000). This biological diversity and the ecosystem services they provide are used for diverse economic activities, such as fishing or aquaculture production, as well as to cover basic needs of hygiene and food (Carrillo et al. 2011; Duque et al. 2018). Consequently, wetlands are important for territorial planning, especially as a figure of *environmental determinants*, a norm of superior hierarchy and of mandatory compliance in land use plans (Jara 2017). (Note: This norm is stipulated specifically for the municipality of Leticia [Corpoamazonia 2014] which is the subject area for this article.)

The wetlands of the Amazon in general and particularly in Leticia, have been significantly transformed by factors, such as pollution, deforestation of their watersheds and riparian vegetation, sedimentation and habitat transformation (Duque 1993; Herrera et al. 2008; Senhadji et al. 2017). According to regional environmental history, the municipality of Leticia (Amazonas, Colombia) was located in a complex network of wetlands (Hoorn et al. 2010), which due to population growth were disappearing and then used for urban development (Vergel 2008). It is therefore important to consider human populations in the environmental, cultural, and social context. Knowing people's perception of the environment helps us understand the environment and human relationships (Calixto and Herrera 2010), as well as social participation in environmental issues (Sureda et al. 2009). Furthermore, it is essential that people understand the attributes of the most diverse biome in the world such as the Amazon forest and its associated ecosystems, in order to initiate or help support actions that lead to the conservation of its megadiversity (Ribas and Aleixo 2019).

The objective of our study was to address the environmental characteristics of wetlands in the urban and suburban area of Leticia and provide insight into their use and current environmental problems. It is hoped that this information will contribute to strengthening territorial and environmental planning strategies and unleash actions to strengthen citizen participation and regional environmental education.

STUDY AREA

The study area of the characterized wetlands in the field and those consulted in Carrillo et al. (2011) is located between 4°1'0" S to 4°14'0" S and 70°1'0" W to 69°53'0" W, in the jurisdiction of the municipality of Leticia (Amazonas, Colombia, Figure 1). The study area of Carrillo et al. (2011) covers three micro-watersheds: Yahuarcaca, Tacana and Pichuna, while our investigation also included work in urban streams (or what are known locally as "caños") and wetlands associated with them, such as the Calderón, Urumutú and Simón Bolívar streams that drain into the Tacana.

According to the Caldas-Lang classification, the climate is *warm-humid* (Rangel and Luengas 1997). The aver-

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age annual precipitation is 3400 mm, with a monomodal rainfall regime, where the highest rainfall occurs between November and May, and the lowest between June and October. The latter is not considered a dry season since the month with the least rainfall exceeds 100 mm (Galvis et al. 2006). The average annual temperature is 25.8°C (IDEAM 2012). The warmest months of the year occur from October to November and between February and March, when the average temperature rises to 28°C. Minimum temperatures occur in June, July, and August, with values close to 24°C (Carrillo et al. 2011), coinciding with the *arú* or *friaje* season, which refers to the arrival of a cold wind that blows through the entire eastern plain of South America from Antarctica (Duque 1993; Caraballo et al. 2014).

The wetlands in the region have a seasonal hydrological behavior because their waters can vary between 10 and 12 m deep (Torres et al. 2013). In the case of the river and lagoon systems associated with the Amazon River and the Yahuarcaca stream, there are four periods: high water between April and May, falling water between June and August, low water mainly in September and rising water until March (Salcedo et al. 2012; Torres et al. 2013).

The study area includes two well-defined morphological units. The first corresponds to the Leticia-Tabatinga terrace and the other to the river floodplain, where the oscillation in the water level of the Amazon River reaches 12 m vertically and causes a horizontal expansion of the water sheet with its suspended load close to 10 km (Jaramillo et al. 2013). This behavior creates unique ecological and hydrological conditions in the wetlands of Leticia (Jaramillo et al. 2013; Arbeláez et al. 2008).

In the southern region of the Colombian Amazon, seven main classes of natural vegetation cover are recognized: high forests (canopy above 25 m), medium forests (canopy between 10-25 m), low forests (canopy < 10 m), alluvial forests, shrublands, grasslands (dominated by non-graminoid herbaceous vegetation) and high savannas (dominated by graminoid herbaceous vegetation) (Rudas 2007). However, in the case of the municipality of Leticia, given the modifications of anthropic origin, that it has suffered especially in the urban area, only a few patches of vegetation remain, such as the site of the old zoo and botanical garden, the forest of the Yahuarcaca stream and its lakes, and the forest of the National University of Colombia

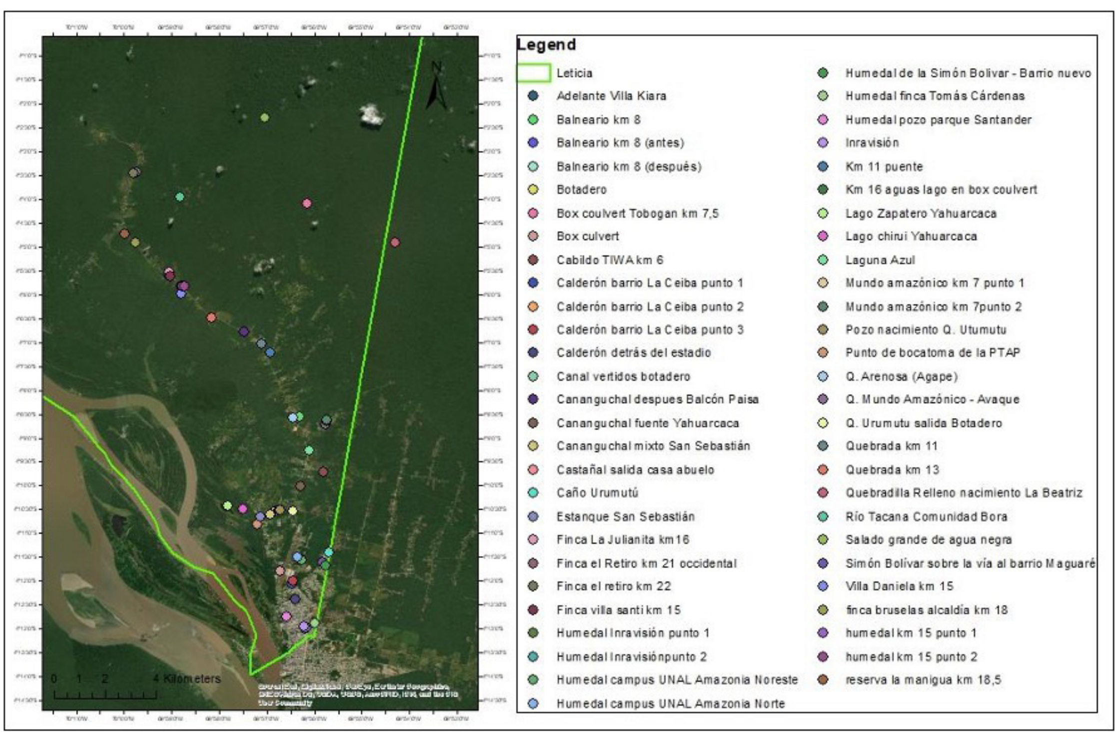

Figure 1. Map showing location of urban and suburban wetlands studied.

Amazon Headquarters (van Vliet and Duque 2019).

METHODS

Field Stage

Wetlands were sampled between May and June of 2021, which corresponds to the period when rainfall begins to decrease and, therefore, coincides with the transition between high water and falling water. Twenty-six wetlands were studied with 46 samples taken for field physicochemical parameters (littoral zone and open water) such as dissolved oxygen (DO), % oxygen saturation, total dissolved solids (TDS), pH (H^+), temperature (°C) and depth (m) with a HANNA HI 98194 Multiparameter probe (Table 1). The selection of wetlands sites was made according to the ease of sampling and granted access.

Data from Carrillo et al. (2011) were used for the characterization of water quality and were collected in the framework of the inter-administrative agreement between the Government of Amazonas and Corpoamazonia. Only the variables collected in the field by the project team were used, and specifically those corresponding to wetlands. In this case, 23 pieces of data from different points on the urban and suburban area of the municipality of Leticia were included.

A 1:100.000 scale map of the wetlands characterized in the field and those from the work of Carrillo et al. (2011) was produced using ArcGIS software version 10.4 and Google Earth Pro (Figure 1).

Laboratory Stage

An analysis of the physicochemical variables of the water was performed with R Studio software using the Principal Component Analysis (PCA) method, which allowed the dimensionality (variables) to be reduced to a smaller number of transformed variables (principal components) that explain the variability of the data (Bro and Smilde 2014). Each principal component would be a linear combination of the original variables and would also be independent or uncorrelated with each other (Bro and Smilde 2014). Initially, the data were arranged in a matrix and then transformed with log (x+1). We then proceeded to run the analysis using the PCA function of the aforementioned program. The total dissolved solids (TDS) variable was discarded since it produced a high collinearity with conductivity.

Perception Surveys

In order to know the perception that the inhabitants of Leticia have about wetlands and their environmental problems, a synchronous survey was carried out through personal interviews of 100 people or by electronic means of people in government institutions, universities and high schools. These surveys asked about the definition that each inhabitant had of what a wetland was, the type of problems and economic activities with the greatest impact on wetlands in Leticia, as well as the benefits they obtained from wetlands and what actions are being taken for their conservation. Perception surveys of the inhabitants of each wetland were conducted during the field campaigns.

To process the responses from the perception surveys, the coding method was used, which consists of reducing the variability of responses to a few types of answers that can be tabulated and analyzed (Rincón 2014). The categories of responses were established beforehand by making a list of these comments and their frequency according to words or phrases with the same meaning, and each grouping was assigned a code that allows its tabulation and subsequent quantitative analysis. For this purpose, a code was designed in Google Colaboratory that uses Python 3 as programming language, with which it was possible to count the frequency of words and categorize them according to the researcher's criteria and the objectives of this study (Popping 2015).

After coding the responses, a Vester Matrix was made to allow for the identification of the causes and effects of environmental problems (Bermúdez and Gómez 2001). This consists of a double-entry format where the identified problems are located, the level of causality between them is established, that is, the relationship of a problem with the others (Bermúdez and Gómez 2001) and allows the qualification of the attributes in the following way:

Not a cause	0
Indirect cause	1
Very direct cause	2

Having established the value of causality in the matrix between all the problems, we proceeded to graph this (Figure 4): the abscissa axis is the one that represents the range of passive problems or consequence problems, and the ordinate axis represents the active problems or cause problems. The sum of the causality/effect that each problem has over the others is the value reflected in the graph.

The active problems represent the problems that have an influence over the other ones, but not by others, which means they are cause problems. The passive problems are those that don't have an important influence over the other problems, but are caused by the majority, which means they are consequence problems. The critical problems usually represent one problem which is a noticeable cause of others, and which is caused by the rest. The indifferent problems represent the problems that don't have any effect of causality on the analyzed set and are not caused by any of

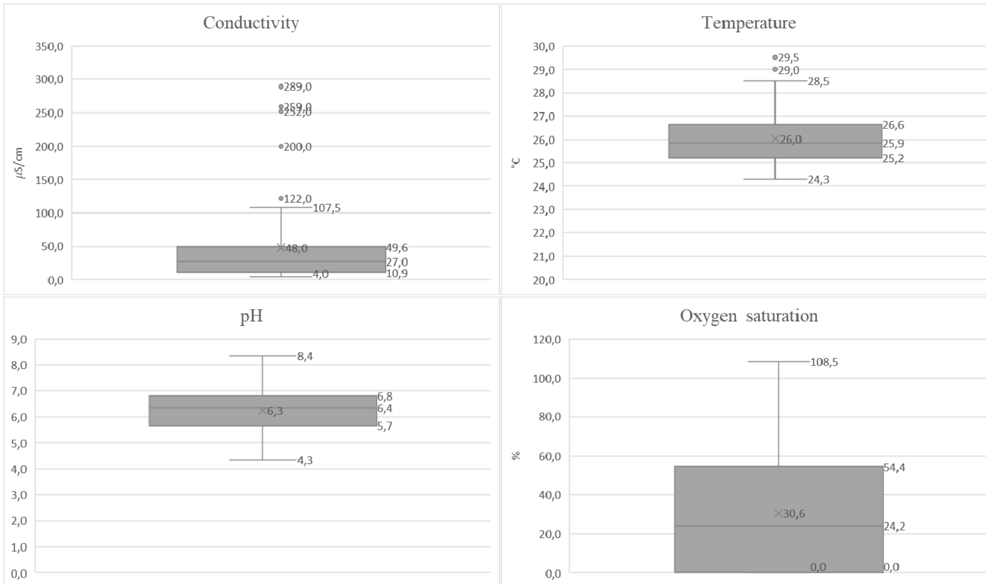

Figure 2. Box plots of conductivity, temperature, pH, and % oxygen saturation. The dark line represents the median of the data, while the shaded box is delimited by the lower quartile and the upper quartile. The small dots, as visualized in the graphs of conductivity and temperature, indicate outliers with values well beyond the normal.

the problems.

Finally, the Vester matrix allows the construction of a problem tree (Figure 5) where problems are put into a hierarchy and prioritized by means of the logical decomposition of cause-effect relationship (Bermúdez and Gómez 2001).

RESULTS

The results from field 46 samples and Carrillo et al. (2011) are presented in Table 1, whereas the variability of the physicochemical data is presented in box plots (Figure 2). It is possible to observe atypical records and extreme cases for conductivity with values above 200 µS/cm, as in the case of the wetlands of Parque Santander, with values of 252 µS/cm and 259 µS/cm; and Calderón, with 289 µS/cm, both in the urban area. These values contrast with the average conductivity of 48 µS/cm. The average temperature is 26.0°C, with atypical values of 29°C and 29.5°C (Figure 2) in Finca El Retiro and Lake Zapatero, respectively. The pH level is in the neutral to acidic range (Figure 2). The average oxygen saturation percentage was 30.6% and several wetlands located in the suburban zones were found to have very low oxygen concentrations, representing hypoxic and in extreme cases anoxic conditions, as is the case of the wetlands of Universidad Nacional Sede Amazonia, Parque Santader, Inravisión, Chirui lake and the streams of Simón Bolívar and Calderón.

The information collected in the field through the characterization sheets (Table 2) shows that the wetlands located in the suburban area have protection figures with respect to urban wetlands. It undoubtedly favors the protection or less impact on these systems. In any case, there are already some wetlands, especially cananguchales, that are being affected by gradually increasing the population density on their territories. Suburban wetlands are mostly associated with La Beatriz and Yahuarcaca streams and to a lesser extent with Pichuna, Tacana, “Agua Negra” and Urumutú streams. The urban wetlands are located in the micro-watershed of the Urumutú stream, the Calderón stream and the Simón Bolívar stream. Less pressure occurs on suburban wetlands, first due to lower population density, second because several of them are located in conservation areas, either in indigenous territories (“resguardos”) or in protection zones of non-governmental organizations (civil society) and third, the suburban sector is important for the leisure time of the Letician people.

Figure 3 represents the Principal Component Analysis (PCA) in which axis 1, associated with conductivity, explains 33% of the variance of the data while axis 2 explains 26.1%. This axis is mainly associated with temperature. By this, we could see that in general the correlation between the variables is low, but those are the variables that can explain most of the variance of the data. The wetlands located to the left of component 1 have a higher percentage of oxygen saturation and correspond in majority to the suburban area of Leticia (orange dots),

Table 1. Physicochemical parameters of Carrillo et al. 2011 (*) and those obtained in the current study (**).

Site	Wetland	% oxygen saturation	Temperature (°C)	TDS	pH	Conductivity (µS/cm)	Depth (m)
1*	Q. km 11	17.5	25.5	7	5.5	7.4	0.42
2*	Q. km 13	14.7	24.5	8	6.4	8.4	0.83
3*	Box culvert	73.3	24.5	49	7.5	36.8	0.39
4*	Castañal exit of Casa Abuelo	13.3	26.4	26	6.6	46.1	0.80
5*	Intake site of PTAP	22.3	25.6	39	6.3	37.5	1.69
6*	San Sebastian pond	21.3	27.0	34	6.3	33.9	0.95
7*	Dump	23.1	25.6	46	7.4	47.7	0.18
8*	Q. Urumutú dump exit	11.4	24.9	108	6.4	107.5	0.48
9*	Channel Spillway dump	15.4	24.6	13	7.3	13.1	1.18
10*	Well source Q. Urumutú	57.2	27.2	26	4.3	25.9	0.15
11*	Cananguchal source Yahuarcaca	55.3	28.4	52	7.2	51.5	0.82
12*	"Azul" lagoon	26.0	26.5	27	8.4	27.4	0.50
13*	Box culvert slide km 7,5	42.5	27.0	21	7.6	21.5	0.40
14*	Between Mundo Amazónico and Avaque	69.4	24.5	30	6.8	29.9	0.47
15*	Balneario km 8, before	74.9	24.3	27	6.6	26.6	1.44
16*	Balneario km 8	64.2	24.9	27	6.6	26.8	0.53
17*	Balneario km 8, after	77.1	24.4	27	6.2	27.2	0.61
18*	Q. Arenosa (Agape)	80.1	24.8	20	6.5	20.1	0.45
19*	Km 11 bridge	36.3	26.1	14	6.8	14.4	0.15
20*	Cananguchal afeter Balcón Paisa	71.2	28.5	13	7.7	12.8	0.56
21*	Km 16 lake water in box coulvert	72.2	26.7	5	5.7	5.4	1.33
22*	Ahead of Villa Kiara	37.1	26.3	5	8.0	5.4	1.03
23*	Q. landfill source La Beatriz	63.9	24,.9	8	5.5	7.7	0.23
24**	La Julianita property (Hábitat Sur) km 16	54.4	25.8	4	5.2	7.0	0.90
25**		0.9	25.8	10	5.8	19.0	0.90
26**	Los Balcones	39.2	26.9	16	5.9	31.0	1.00
27**		36.4	26.9	4	5.6	8.0	1.00
28**	El Retiro km 22	108.3	29.0	3	5.2	5.0	1.50
29**		45.4	27.7	4	5.1	7.0	1.50
30**		108.5	26.0	4	5.5	8.0	1.50
31**	Villa Santi km 15	24,.3	26.1	15	5.8	24.0	0.00
32**		26.0	26.4	8	5.5		0.00
33**	Bruselas Alcaldía property km 18	1.3	25.4	4	4.8	8.0	2.00
34**		0.0	25.0	4	4.8	8.0	2.00

Site	Wetland	% oxygen saturation	Temperature (°C)	TDS	pH	Conductivity (µS/cm)	Depth (m)
35**	La Manigua reserve km 18,5	44.5	26.6	8	5.2	19.0	2.00
36**		57.9	26.4	4	5.0	8.0	2.00
37**	Mundo Amazónico km 7	46.9	24.9	15	6.4	29.0	0.60
38**		0.0	25.8	16	6.0	32.0	0,.60
39**	Villa Daniela km 15	21.2	26.9	16	5.8	25.0	3.00
40**		22.1	26.8	10	5.9	16.0	3.00
41**	Wetland km 15 site 1	5.5	24.9	7	5.4	15.0	2.00
42**	Wetland km 15 site 2	0.0	25.2	4	5.3	8.0	0.50
43**	Cabildo TIWA km 6	0.0	25.0	9	5.9	18.0	1.50
44**		0.0	25.1	9	5.6	18.0	1.50
45**	San Sebastián cananguchal	0.7	25.2	17	5.9	33.0	0.20
46**		0.0	25.2	13	5.7	13.0	0.20
47**	Chirui lake Yahuarcaca	0.0	26.6	62	6.8	127.0	5.50
48**		0.0	26.4	61	6.8	122.0	5.50
49**	Zapatero lake Yahuarcaca	54.1	29.5	63	7.2	126.0	7.00
50**		0.0	26.6	63	6.9	126.0	7.00
51**	Tacana river Bora community	65.9	25.4	2	57	4.0	1.50
52**	Salado grande of Agua Negra	26.2	27.2	47	6.4	94.0	0.27
53**		31.5	25.5	5	5.4	9.0	0.27
54**		69.1	25.4	2	5.8	5.0	0.27
55**	Calderón behind the stadium	0.0	26.1	145	6.8	289.0	0.20
56**	Calderón La Ceiba neighborhood	0.0	26.7	23	6.4	47.0	0.77
57**		0.0	25.5	35	6.5	70.0	0.77
58**		24.1	26.3	99	6.5	200.0	0.77
59**	Simón Bolívar on the road to the Manguaré neighborhood	0.0	25.2	39	6.4	78.0	0.00
60**	Caño Urumutú	48.9	25.9	22	6.8	44.0	0.00
61**		54.5	26.1	20	6.6	40.0	0.00
62**	Wetland of the Simón Bolivar - Barrio nuevo	0.0	25.2	42	6.6	84.0	0.50
63**	Inravisión wetland	0.0	25.4	29	6.1	59.0	0.00
64**		0.0	25.7	18	6.4	36.0	0.00
65**	Wetland well of Parque Santander	0.0	26.4	126	7.0	252.0	0.00
66**		0.0	26.3	129	7.0	259.0	0.00
67**	Wetland of Tomás Cárdenas property	54.0	28.0	18	7.1	36.0	0.00
68**		27.6	27.6	14	6.8	27.0	0.00
69**	Wetland of UN Amazonia campus northeast	0.0	25.3	44	6.3	92.0	0.21
70**	Wetland of UN Amazonia campus north	0.0	25.5	45	6.8	87.0	0.35

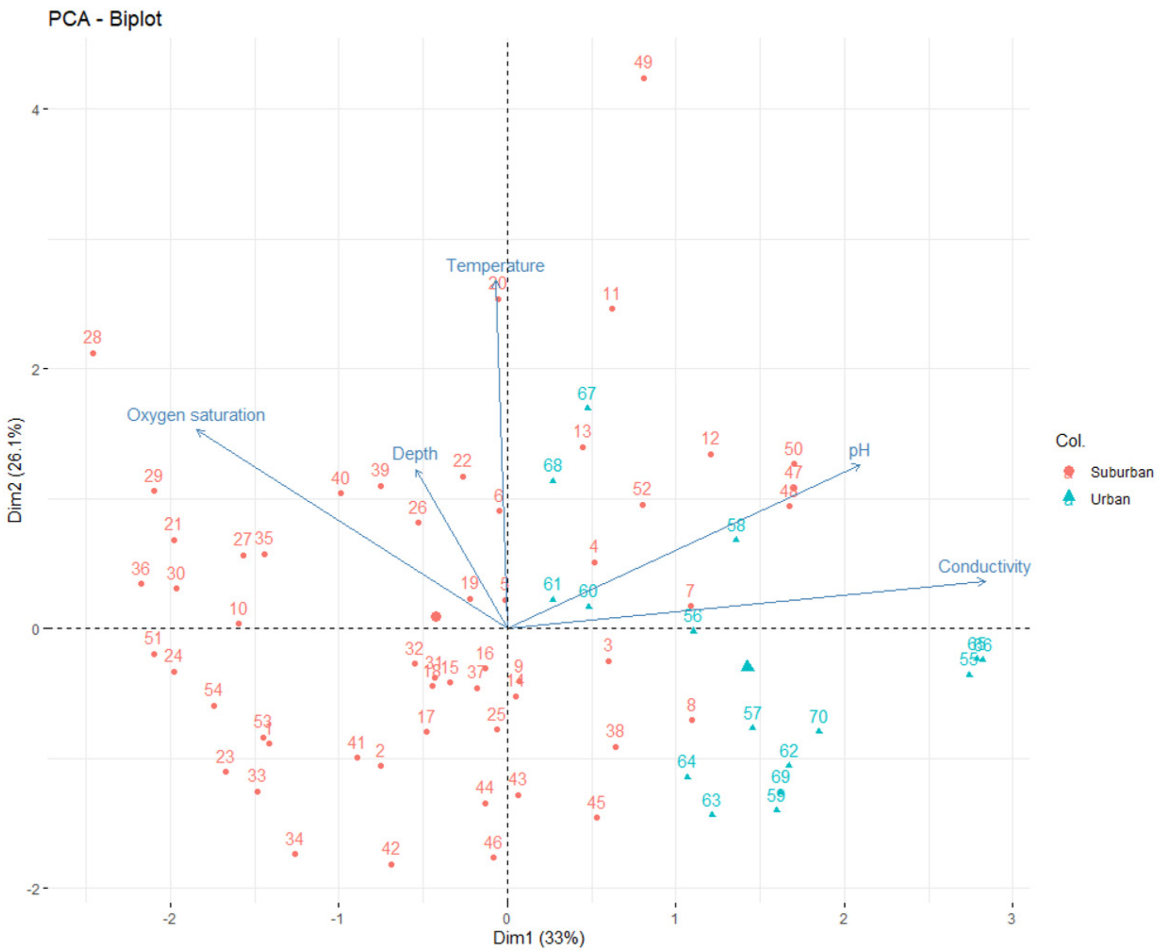

Figure 3. Principal Component Analysis (PCA) of physicochemical variables for the sampled wetlands (our sites plus those of Carrillo et al. 2011; see Table 1 for site names).

which means better water quality conditions. On the other hand, the urban wetlands (green dots) are the ones with highest conductivity, as is the case of Calderón stream (points 55 and 58) along with the wetland well of Parque Santander (point 66), which means an increased amount of minerals explained by domestic wastewater discharge. It can be also seen that depth variable does not explain much of the variance of the data, since its vector that represents the correlation with the other ones has a lower value (shorter).

The urban wetlands that have an optimal environmental quality are located on the premises of the Institute of Radio and Television (Inravisión) and the National University of Colombia (Amazon Headquarters), which have a high degree of protection: the former for being in a private area and the latter for being categorized as environmental heritage of the University. On the other hand, human settlements were found on the margins of the streams (Calderón wetland) indicating that there is no compliance with minimum riparian corridor. A recent resolution of the entity responsible for the environment in the region (Corpoamazonia), resolved in 2020 that wetlands and their water rounds are environmental determinants. In other words, in the improvements and adjustments of what is called territorial planning in Colombia, wetlands must be incorporated (e.g., taken into account).

The results obtained from the field analysis on the problems and economic activities coincided with the perception of the inhabitants - where urbanization (and all processes and activities that it entails) is the main problem affecting the wetlands of Leticia. The results also suggest that 91.8% of those surveyed consider that there is at least one problem in the wetlands of Leticia and more than 80% mentioned contamination by solid waste and the dumping of domestic wastewater.

The perception survey results show that urbanization is the most critical problem facing wetlands in Leticia (Figure 4). Land use changes related to urbanization pose the greatest threat to wetlands. Deforestation, filling, draining, and illegal settlements are "*active problems*" while contamination by solid waste and the introduction of invasive species are "*passive problems*" recognized by the survey participants. Finally, the *indifferent problems* are dumping of domestic wastewater, damming and hydraulic regulation, which represent activities that have no causal effect on the analyzed set. Also, agricultural activities (poultry, fish, and livestock) generate negative impacts (pollution and habitat transformation) which are more evident in the suburban area.

The construction of the problem tree (Figure 5) allowed defining the main problem that is affecting the wetlands, corresponding to urbanization. When building a house, a road or any other artificial structure, people look to the necessity of cutting down trees, filling and draining the humid zones and not to adapt themselves to these conditions. Additionally, some social problems that occur elsewhere in the region or in the country (which we do not analyze in this article) have created some displacements to the municipality of Leticia generating illegal settlements in apparently "wasteland" areas, which later become more urban areas. Finally, as a consequence of all the processes involved in urbanization, added to an inadequate planning of the city, it can be observed that contamination by solid wastes and by domestic wastewater provide evidence of a lack of proper waste separation in Leticia. All of this ends up transforming the initial conditions of wetlands and reducing their environmental quality.

The results of the characterization visits and perception surveys indicated that the main benefits obtained from wetlands are, in order of importance, food (such as fruits or seeds) and medicines from vegetation, followed by water regulation and water availability. Other uses include recreation either in the form of tourism or as local entertainment, cultural or sacred resources, and fishing. The wetlands used as examples for environmental education and scientific research are the wetlands of the National University of Colombia Amazon campus, Mundo Amazónico wetland and Hábitat Sur Natural Reserve. These in turn have protection mechanisms for their conservation. The wetland that stands out for having a cultural use is Zapatero Lake, which has a special and sacred protection for the Organization of Artisanal Fishers of the Yuhuarcaca Lakes (TIKA). Indigenous peoples when living and coexisting with nature have developed mechanisms of relationship with nature, which are necessary for their survival and behavior. Like environmental regulations, sacred themes are control mechanisms to protect nature.

DISCUSSION

Since Humboldt's time in the Amazon (19th Century) there has been talk of colored rivers (Sioli 1967), recognizing three types: white, black, and clear waters. In the southern region of the Colombian Amazon these same considerations have been taken into account, but showing some differences with Sioli's classification, who worked more in the central Brazilian Amazon. In Colombia and in particular in the region of Leticia there are white waters type I and black waters type I, due to a geographical and geological difference that occurs with more northern sectors of the basin in Colombia where they are of type II. Thus, lakes Zapatero and Shirui, when being affected by the Amazon River, are type I whitewater wetlands with conductivities higher than 100 µS/cm while the rest of the wetlands have type I blackwater and their conductivity is always lower than this value (Duque 1997; Núñez-Avellaneda and Duque 2001). Therefore, the higher values found in some urban wetlands, such as Parque Santander and those associated to Calderón micro-basin, are due to a clear disturbance of these systems by human action.

The examination of environmental variables in the urban and suburban wetlands of the municipality of Leticia reveals an axis of variation in water quality and ecological status in general. The gradient is explained by changes in conductivity and low oxygen content, in addition to habitat transformations (littoral zone and riparian vegetation), particularly in urban wetlands.

It is important to consider that hypoxic conditions, explained by high rates of organic matter decomposition (Junk et al. 2012) and intense metabolic activity (Lampert and Sommer 2007; Salcedo et al. 2012), are typical of Amazonian wetlands and in broad terms of shallow tropical lakes. However, anthropogenic actions such as deforestation of the watershed and riparian vegetation (Trancoso et al. 2009), urbanization (Senhadji et al. 2017) and wastewater discharges (Cardona 2020), are influential factors of high impact that are transforming wetlands and explain the environmental axis in the ecological conditions found in the wetlands of Leticia.

The results obtained coincide with those found by Carrillo et al. (2011) who concluded that the main source of wetland contamination comes from the dumping of wastewater by communities located on the banks of streams and the disposal of solid waste into water bodies. These aspects are the consequence of the urbanization of the wetlands of Leticia. This agrees with Paredes (2010) who mentions that solid waste is the obvious threat to urban wetlands. While urbanization is not a recent process in the Amazon (Heckenberger et al. 2008), urbanization processes have accelerated and have led to the transformation of wetlands

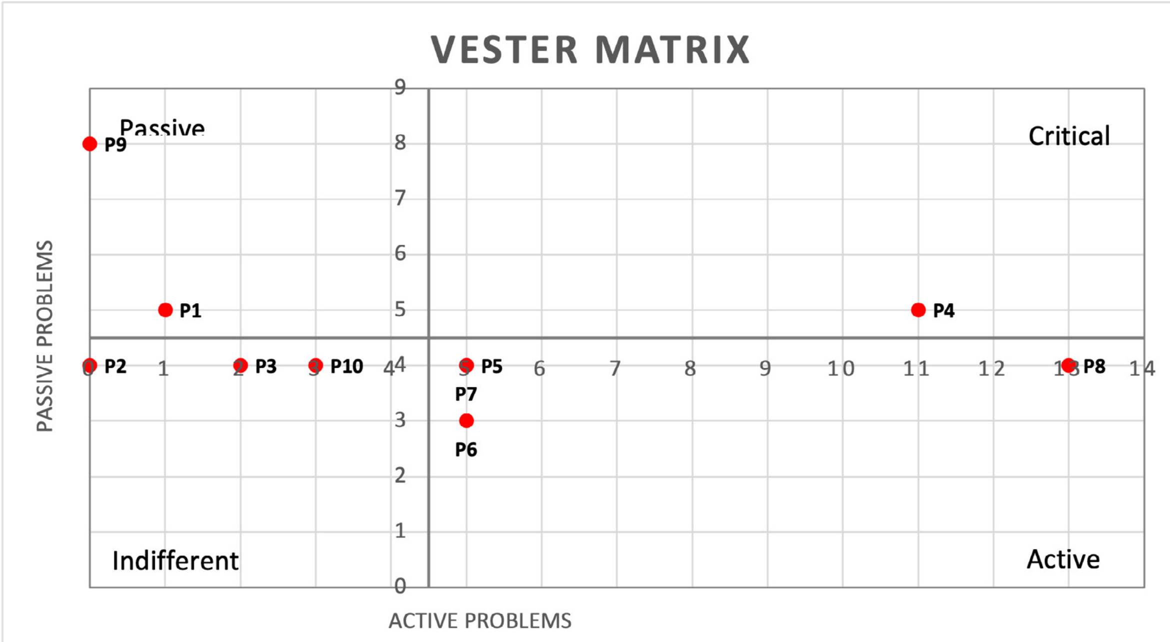

Figure 4. Results of Vester matrix for environmental problems and impacts of the wetlands in Leticia. P1: Solid waste contamination, P2: Dumping of domestic wastewater, P3: Dammed, P4: Urbanization, P5: Deforestation, P6: Filling, P7: Drainage, P8: Illegal settlements, P9: Species introduction, P10: Hydraulic regulation.

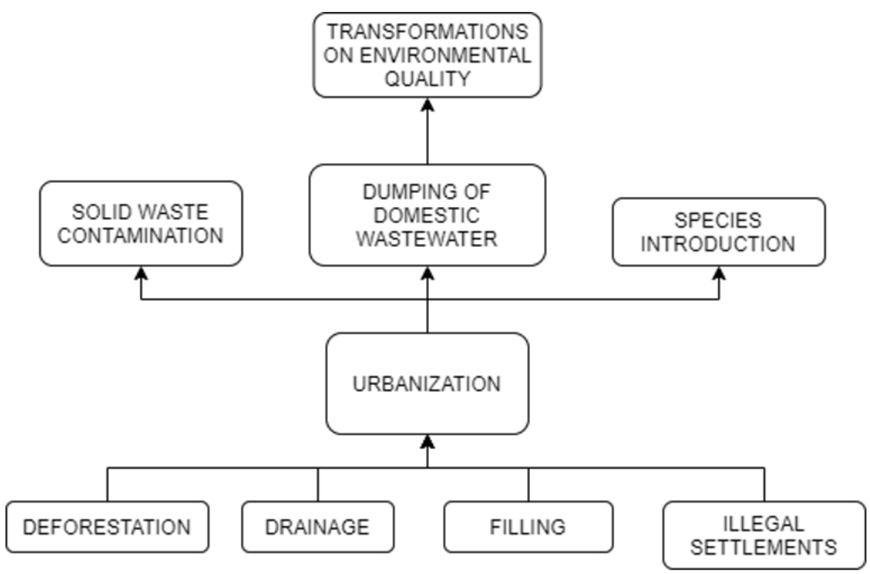

Figure 5. Problem tree of the wetlands in Leticia.

Table 2. Location, sample date, property type, protection status, neighborhood or path, and micro-basin associated with the visited wetlands in the municipality of Leticia. *AICA: Area of International Importance for Bird Conservation.

Wetland	Name	Location		Date (DD/MM/YY)	Zone	Property	Protection	Neighborhood/Path	Micro-basin
		Latitude	Longitude						
H1	La Julianita property km 16	-4,092060	-69,984260	4/5/2021	Suburban	Private	Natural reserve of civil society	*Leticia-Tarapacá km 16*	La Beatriz
H2	Los Balcones property km 21	-4,057190	-69,995470	4/5/2021	Suburban	Private	Private property	*Leticia-Tarapacá km 21*	Tacana
H3	El Retiro property km 22	-4,057550	-69,996640	4/5/2021	Suburban	Private	Private property	*Leticia-Tarapacá km 22*	Pichuna
H4	Villa Santi property km 15	-4,093690	-69,983860	4/5/2021	Suburban	Private	None	*Leticia-Tarapacá km 15*	La Beatriz
H5	Bruselas Alcaldía property km 18	-4,082010	-69,996050	7/5/2021	Suburban	Private	City hall property	*Leticia-Tarapacá km 18*	La Beatriz
H6	La Manigua reserve km 18,5	-4,078760	-69,999580	7/5/2021	Suburban	Private	Forest reserve	*Leticia-Tarapacá km 18.5*	La Beatriz
H7	Mundo Amazónico km 7	-4,144070	-69,929120	11/5/2021	Suburban	Private	Natural reserve of civil society	*Leticia-Tarapacá km 7*	Yahuarcaca
H8	Villa Daniela km 15	-4,099903	-69,979869	11/5/2021	Suburban	Private	Private property	*Leticia-Tarapacá km 15.2*	La Beatriz
H9	Wetland km 15 site 1	-4,097334	-69,979464	11/5/2021	Suburban	Private	None	*Leticia-Tarapacá km 15.5*	La Beatriz
H10	Wetland km 15 site 2 ("Ojo de agua")	-4,097259	-69,978813	11/5/2021	Suburban	Private	Private property	*Leticia-Tarapacá km 15.5*	La Beatriz
H11	Indigenous Council TIWA km 6	-4,162020	-69,930034	11/5/2021	Suburban	Public	In process of constitution as an indigenous settlement	*Indigenous council (km 6)*	Yahuarcaca
H12	Mixed cananguchal San Sebastián	-4,176890	-69,948750	18/5/2021	Suburban	Private	None	*San Sebastián, 50m from the old landfill*	Urumutú
H13	Chirui lake Yahuarcaca	-4,175005	-69,958320	18/5/2021	Suburban	Public	AICA* and special protection area under the organization's fishing agreements TIKA	*Chirui lake of lagoon system of Yahuarcaca*	Yahuarcaca and Amazonas river
H14	Zapatero lake Yahuarcaca	-4,174060	-69,963780	18/5/2021	Suburban	Public	AICA* and special protection area under the organization's fishing agreements TIKA	*Zapatero lake of lagoon system of Yahuarcaca*	Yahuarcaca and Amazonas river
H15	Tacana river Bora community	-4,066070	-69,980347	23/5/2021	Suburban	Public	Indigenous territory	*Bora community km 17*	Tacana
H16	Salado Grande of Agua Negra	-4,038425	-69,950658	23/5/2021	Suburban	Public	Indigenous territory	*Indigenous teeritory Ticuna - Huitoto km 6-11*	Agua Negra
H17	Calderón behind the stadium	-4,206667	-69,939861	28/5/2021	Urban	Public	None	*José María Hernández*	Calderón
H18	Calderón La Ceiba neighborhood	-4,201056	-69,941250	28/5/2021	Urban	Public	None	*La Ceiba*	Calderón
H19	Simón Bolívar on the road to the Manguaré neighborhood	-4,193750	-69,930444	28/5/2021	Urban	Public	None	*Barrio Nuevo*	Simón Bolívar
H20	Caño Urumutú	-4,190389	-69,928000	28/5/2021	Urban	Public	None	*Tabatinga*	Urumutú
H21	Wetland of Simón Bolivar - Barrio Nuevo	-4,194667	-69,929417	28/5/2021	Urban	Public	None	*Barrio Nuevo*	Simón Bolívar
H22	Inravisión wetland	-4,216654	-69,936481	1/6/2021	Urban	Public	None	*Avenida Internacional*	None

Table 2 Continued. Location, sample date, property type, protection status, neighborhood or path, and micro-basin associated with the visited wetlands in the municipality of Leticia. *AICA: Area of International Importance for Bird Conservation.

Wetland	Name	Location		Date (DD/MM/YY)	Zone	Property	Protection	Neighborhood/Path	Micro-basin
		Latitude	Longitude						
H23	Wetland well of Parque Santander	-4,212647	-69,942997	1/6/2021	Urban	Public	None	*Centro*	None
H24	Wetland of Tomás Cárdenas property	-4,214870	-69,933270	1/6/2021	Urban	Private	None	*Barrio Costa Rica*	None
H25	Wetland of UN Amazonia campus northeast	-4,192999	-69,937629	4/6/2021	Urban	Public	Environmental heritage of Universidad Nacional de Colombia Sede Amazonia	*Km 2 antigua vía Tarapacá*	Urumutú
H26	Wetland of UN Amazonia campus north	-4,191590	-69,939163	4/6/2021	Urban	Public	Environmental heritage of Universidad Nacional de Colombia Sede Amazonia	*Km 2 antigua vía Tarapacá*	Urumutú

in Leticia. The wetland well of Parque Santander located in the center of Leticia, provides an extreme example. Here high levels of conductivity and hypoxic conditions have led to eutrophication of the water supply which has been replaced by pumping water sources from the municipal aqueduct. This transformation of urban environments not only has effects on natural conditions, but also impacts environmental uses or benefits, as it modifies the supply of ecosystem services (Horwitz and Finlayson 2011).

Finally, while there are several policies and regulations to protect and conserve wetlands in Colombia, these have not been successful. Therefore, it is necessary to encourage, support and finance participatory research of citizen science projects in order to make the inhabitants appropriate the value of the cultural and environmental heritage of these wetlands (Contreras 2002). Policies should not only take into account the ecological particularities but also the cultural, political and economic context of the region.

CONCLUSION

Regarding environmental quality, differences were found between urban and suburban wetlands in the municipality of Leticia. These differences generate a gradient in conductivity, pH, temperature, and oxygen concentration. Despite the problems facing wetlands in Leticia, particularly urban wetlands, 94.8% of respondents considered wetlands important for their well-being and 97.9% emphasized the value of wetland conservation and restoration. The findings of this research provided information on the causes of the decrease in the environmental quality of wetlands in the municipality of Leticia and will hopefully aid ongoing efforts to improve territorial planning and environmental management.

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