AMAZON PROJECT
REGIONAL ACTION IN THE AREA OF WATER RESOURCES

ANA
NATIONAL WATER AND SANITATION AGENCY - BRAZIL

ACTO
Amazon Cooperation Treaty Organization

ABC
BRAZILIAN COOPERATION AGENCY
MINISTRY OF FOREIGN AFFAIRS

MINISTRY OF FOREIGN AFFAIRS
FEDERATIVE REPUBLIC OF BRAZIL

STATUS OF WATER QUALITY IN THE

AMAZON BASIN

EXECUTIVE SUMMARY

ELABORATION OF THE REPORT ON THE STATUS OF WATER QUALITY IN THE AMAZON BASIN

EXECUTIVE SUMMARY

1ST EDITION | 2023 | BRASILIA

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ACTO - Amazon Cooperation Treaty Organization
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General Note: This study was conducted considering the hydrological limit of the Amazon Basin, and for this reason, Suriname, was not considered in the analyses of the study in question, even though it is a Member Country of ACTO, as it does not have a hydrological contribution area in the Amazon Basin. According to the Amazon Cooperation Treaty (ACT), the results of this study will be beneficial to all 8 Member Countries, including Suriname despite not being part of the hydrographic basin.

It is important to emphasize that the consultancy for preparing the Report on the Status of Water Quality in the Amazon Basin had the effective monitoring of the ACTO team, especially for management issues, and ANA, for technical issues. This dynamic was carried out directly on all the products delivered through written technical evaluations and various meetings.

Note from Venezuela: In the case of the Bolivarian Republic of Venezuela, data from the Brazo Casiquiare and Río Negro, which correspond to the Venezuelan Amazon, were considered.

STAMP

Meeting of the waters | Manaus. Brazil | ACTO Image Bank

Scarlet Macaws | ACTO Image Bank

ICAO Image Bank

Napo River | Ecuador | ACTO Image Bank

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PREFACE

The "Amazon Project - Regional Action in the area of Water Resources" is an initiative of the eight Amazon countries: Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, Suriname, and Venezuela implemented through the Amazon Cooperation Treaty Organization (ACTO) with the technical and financial cooperation of the National Water and Basic Sanitation Agency (ANA) and the Brazilian Cooperation Agency (ABC/MRE).

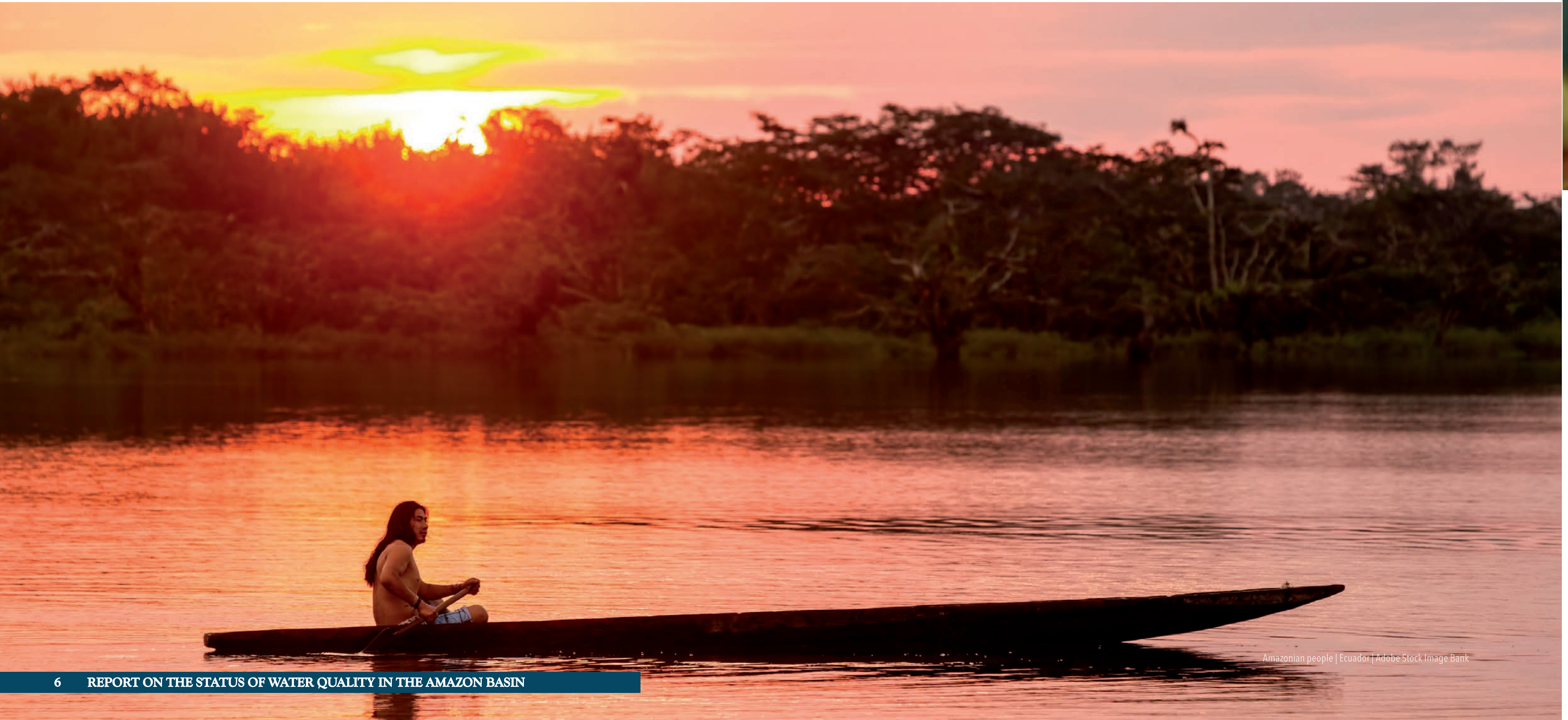
The project aims at strengthening cooperation among Amazonian countries and promote integration in this globally important region with a view to planning and implementing strategic actions for protecting and managing transboundary water resources.

The project, which begun in 2012 and is now in its second phase, is aligned with the Amazonian Strategic Cooperation Strategic and the Amazon Cooperation Treaty (ACT-1978), in which the Member Countries assumed, among others, the commitment to cooperate towards promoting the rational use of water resources, which is essential for the sustainable development of the Amazon basin, home to more than 33 million people. Water quality management is a common challenge, so it is a pleasure to present this executive summary of the Report on the Status of Water Quality in the Amazon Basin that will benefit this essential component of the project - the managers of water resources in the Amazon Basin, and is the result of the joint work of the institutions of the 8 Amazonian countries responsible for public policies devoted to the environment and management of water resources, which have provided monitoring data from their national networks. The document reveals the main vectors that impact the quality of Amazonian waters resulting in the loss of biodiversity, increase of water-borne diseases, reduction of fishing, and loss of tourism, cultural and landscape values, among others.

These type of studies are essential to properly inform and involve society, contributing to establishing public policies to protect, recover, and monitor aquatic ecosystems. In addition, they fit into the dynamic content of the Amazon Regional Observatory, which is the most important tool for strengthening ACTO in its mission to promote sustainable development in the Amazon. The full text of the Diagnosis will be available on the ACTO website (www.otca.org).

This publication wil contribute to the comprehensive and integrated management of water resources in the Amazon Basin.

Permanent Secretary of the ACTO
National Water and Basic Sanitation Agency (ANA)
Brazilian Cooperation Agency (ABC/MRE)



Amazonian people | Ecuador | Adobe Stock Image Bank

INTRODUCTION

Cabo Pantoja | Peru | ACTO Image Bank

The Amazon has a unique attribute: grandeur! Everything associated to this region is superlative, challenging, and sometimes immeasurable. To be able to act in this unique territory and protect its wealth, it is essential to know its peculiarities and characteristics.

The Amazon is characterized by its extraordinary biodiversity and extensive hydrographic network, besides the vast cultural diversity stemming from a historical process of occupation of the territory and the interaction among human groups of different ethnic and geographic origins. Such aspects, added to its essential role concerning climate regulation, significantly influence the transport of heat and water vapor to regions with higher latitudes, as well as the fundamental carbon sequestration, which helps reduce global warming. For this reason they have attracted the world's attention (ACTO, 2022).

Known as the largest rainforest, representing one third of the world's tropical forests, the Amazon is home to around 30,000 species of plants, 3,000 species of fish, 384 species of amphibians, 550 species of reptiles, 950 species of birds, 350 species of mammals and 57 species of primates (ACTO, 2022).

The Amazon River Basin (ARB) is the largest river basin on the planet, occupying 5.9 million km^2 (ANA, 2017) and joining territories of seven countries: Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru and Venezuela, housing about 33 million people (Adapted from IBGE, 2020 and ACTO, 2021).

In hydrological terms, after the meeting of its tributaries (Negro and Solimões rivers), the quantity of water transported in the Amazon river bed varies from 220 thousand m^3/s to 300 thousand m^3/s in the rainy season. No other river in the world is anywhere near this size; thus, it is considered the river with the most significant volume of water on the planet and has as its main tributaries the Putumayo, Japurá, and Negro rivers (northern slope), Juruá, Purus, Madeira, Tapajós and Xingu (southern slope) (ACTO, 2022).

The vast distances between urban centers; the boats as primordial for the transportation system in the region; the challenges for the supply of electricity, internet, among other goods and services; the exuberance and adversities of the Amazon forest and the coalition of eight countries to harmonize the management of its waters are some of the singularities of the Amazon Basin (SATHLER; MONTE-MÓR; CARVALHO, 2009).

On the other hand, all this wealth has been undergoing significant changes over time, both in the population contingent and in the ways of exploiting the territory. The changes put at risk the natural and cultural stability of the region as a whole, with direct effects on water availability, in quantitative and qualitative terms (Elaboration by COBRAPE, 2022).

Culturally treated as an infinite good, water has proved to be an increasingly scarce resource due to the growing consumption of the most diverse uses, so managers are faced with the major challenge of ensuring access to water in quantity and quality for future generations and overcoming the region's low socioeconomic dynamism (Elaboration by COBRAPE, 2022).

The need for cooperation among countries arises, both in sharing technical and scientific information on the hydrographic basin and in the reasonable and equitable use of water resources.

In light of this, the eight Amazonian countries signed the Amazon Cooperation Treaty (ACT) on July 3, 1978, with the objective of promoting the harmonious development of the Amazonian territories in such a way that joint actions of the Amazonian countries produce equitable and mutually beneficial results in achieveing the sustainable development of the Amazon Region. As part of the Treaty, the Member Countries made a joint commitment to the preservation of the environment and the rational use of the Amazon's natural resources (ACTO, 2023).

Subsequently, in 1995, the eight countries created the Amazon Cooperation Treaty Organization (ACTO) as a forum for political dialogue and regional cooperation. With the creation of ACTO, joint actions for the harmonious development of the Amazon countries began to be implemented, until in 2010, the approval of the Amazonian Strategic Cooperation Agenda for (ASCA), which establishes the vision, mission, and strategic objectives of ACTO, in addition to defining the thematic axes and activities for cooperation, places on the agenda the integrated management of water resources in the Amazon Basin. In this context, the topic of water is prioritized to adopt an integrated approach to managing water resources in the Basin through the Strategic Action Program (SAP) (ACTO, 2023).

The Strategic Action Program, in turn, is an instrument that guides regional cooperation and the actions of the Member Countries, which requires support from the highest level of the relevant government sectors since it establishes strategies and priorities for regional action while offering policy and regulatory delineations in the context of institutional strengthening. The Amazon Project, which began in 2012, set various technical cooperation actions between the Member Countries, including water monitoring and management of water resources, seeking a greater leveling of installed capacities of the entities involved in this area (ACTO, 2023).

In the wake of this development, the Report on the Status of Water Quality in the Amazon Basin (RSWQAB) was prepared, encompassing seven products, to provide adequate and contextualized knowledge on the current surface water quality status in the Amazon Basin. The primary purpose is to support decision-makers in the Amazon countries in defining public policies and strengthening the integrated management of water resources.

1. CONCEPTUAL AND METHODOLOGICAL BASIS

Amazon Forest | Tarapoto - Peru | Adobe Stock Image Bank

After specifying the content, methodology, and premises for the study, videoconferences were held with each of the Member Countries to define the objectives of the work to be conducted and indicate which data would be needed for the full development of the consultancy (Figure 1). As a result of the meetings, water quality monitoring data from 2000 to 2019 were obtained, compiled, and standardized, along with information related to the institutional management and shared management among neighboring countries, and the identification of good practices to improve water quality in the Amazon Basin, including national and regional actions and an initial survey of the pressures that directly affect water quality. This information, together with other relevant data for the study, is available in the **Context of the water quality status in the Amazon Basin countries.**

With the monitoring data and within the scope of the **Diagnosis and baseline on the quality of surface water in the Amazon Basin**, the Pressure-State-Response (PSR) methodology was applied to diagnose the water quality situation in water bodies in the region. The PSR methodology is based on the idea that human activities exert pressure on the environment, affecting the status of quality and quantity of natural resources and that society, in turn, responds to these changes through the proposition of environmental, economic, and sectoral policies, in addition to changes in its behavior.

With these results, the best global practices in cross-border water sharing were evaluated to design a **Proposal for the integral management of the water quality in the Amazon Basin.** It includes a set of proposals for specific measures and actions to be developed at the sub-national, national, and intergovernmental cooperation levels of ACTO, based on systematized best practices to contribute to a better management, monitoring, and control of water quality in the ARB.

To validate these propositions ensuring maximum convergence and adherence with the different regional realities, interviews were carried out with representatives of Member Countries through written questionnaires and videoconferences to learn about the multiplicity of visions related to the region's development and the preferences towards water quality.

These interviews brought up perceptions, priorities, suggestions of guidelines, and action projects to subsidize the **Proposal for the integral management of the water quality in the Amazon Basin**. The interviews captured the expectations and orientations related to the region's development, allowing the evaluation of potential programs and priority fields of action on water quality.

The AAR also includes the **Articulation and Coordination Report with other studies and processes in the Amazon Basin.** It presents studies with which it has or should have a direct relationship envisaging integration.

It also incorporates the **Database** to properly store and provide all the data and information produced under the study. A Geographic Database (BDG) enables the provision of data for other services, such as for the Amazon Regional Observatory system (ORA - https://oraotca.org/pt/), which are in line with each other, enabling perfect integration for storing, manipulating, visualizing, and sharing geographic data.

The study leads to two final reports. The **Final Report** consolidates all the primary information gathered during the study, that is, the "status" in qualitative terms of the water situation at the national and regional levels of the Amazon Basin, and this Executive Summary introduces a synthesis of the results achieved.

In addition, strategic meetings were held between the Cobrape and ACTO/ANA team with the consultants responsible for preparing other studies of the entity in the region and that are directly related to the RSWQAB to meet in full the object of the contract, showing the current status of water quality in the Amazon Basin.

Figure 1. Illustrated summary of the project route

The Amazon River Basin (ARB) covers an area of approximately 5.9 million km², from the Peruvian Andes, where lies the source of the Solimões River, to the mouth of the Amazon River in the Atlantic Ocean (ANA, 2015). According to the National Agency of Waterway Transport of Brazil (ANTAQ, 2013), the basin has about 25,000 km of navigable rivers, making it the most extensive hydrographic network.

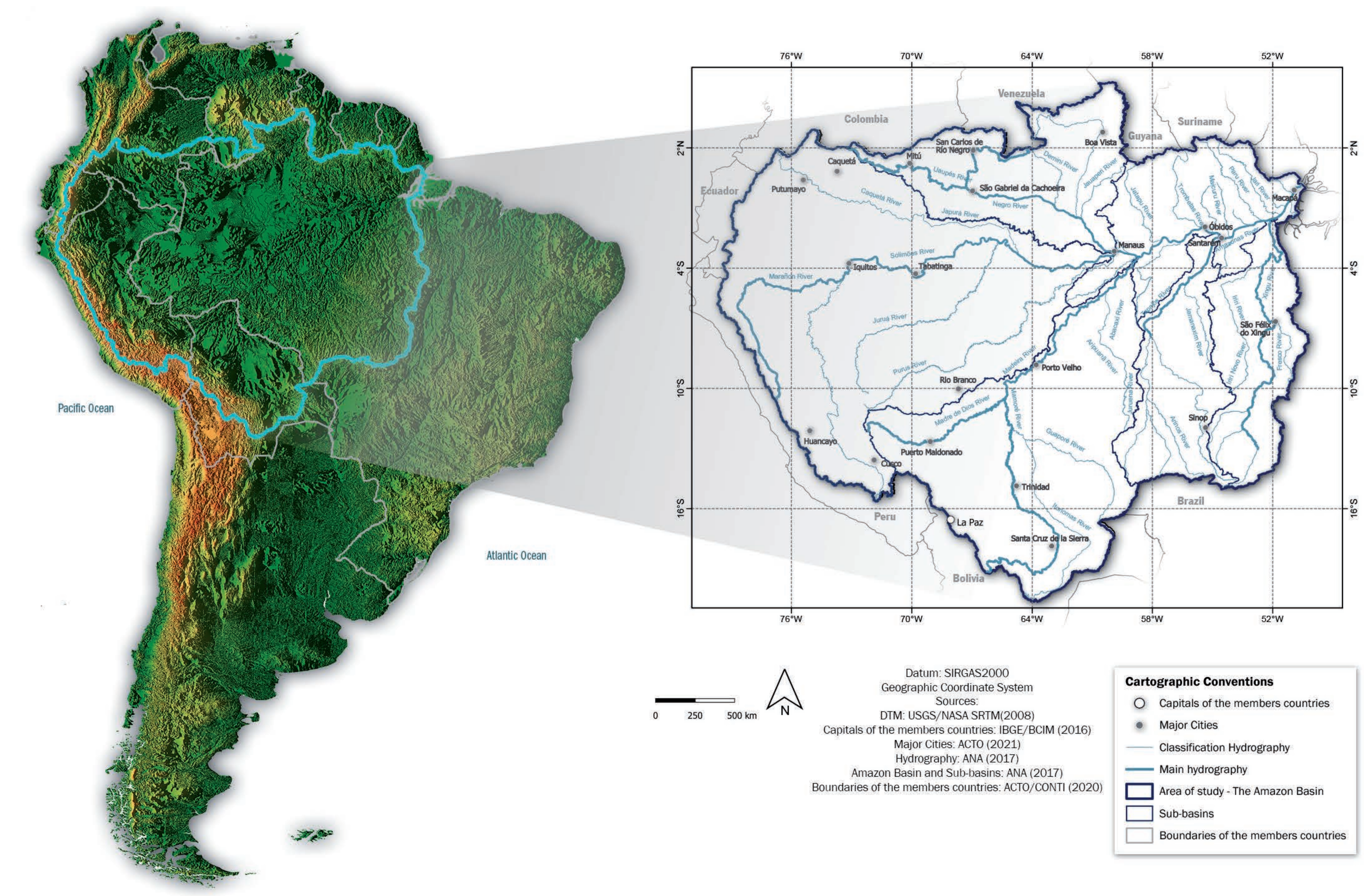
This entire area encompasses seven countries: Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, and Venezuela. In the particular case of Suriname, which is also an ACTO Member Country, there is no water contribution area for the purposes of this study. Table 1 shows the area occupied by the country and Figure 2 shows ARB area considered the for this study.

Table 1. Area of Countries in the Amazon Basin

Country	Country area (km²)	ARB country area (km²)	% of the country area in thetotal area of the ARB
Bolivia	1,089,314	713,152	12.06%
Brazil	8,515,707	3,709,067	62.73%
Colombia	1,133,063	345,462	5.84%
Ecuador	248,619	131,265	2.22%
Guyana	209,902	12,565	0.21%
Peru	1,291,221	961,459	16.26%
Venezuela	912,235	39,626	0.67%
	Total	**5,912,598.61**	**100%**

Source: Calculated by intersecting the IBGE administrative base (2016) and the ANA ottocoded base (2017)

Figure 2. Location of the Amazon River Basin and main rivers

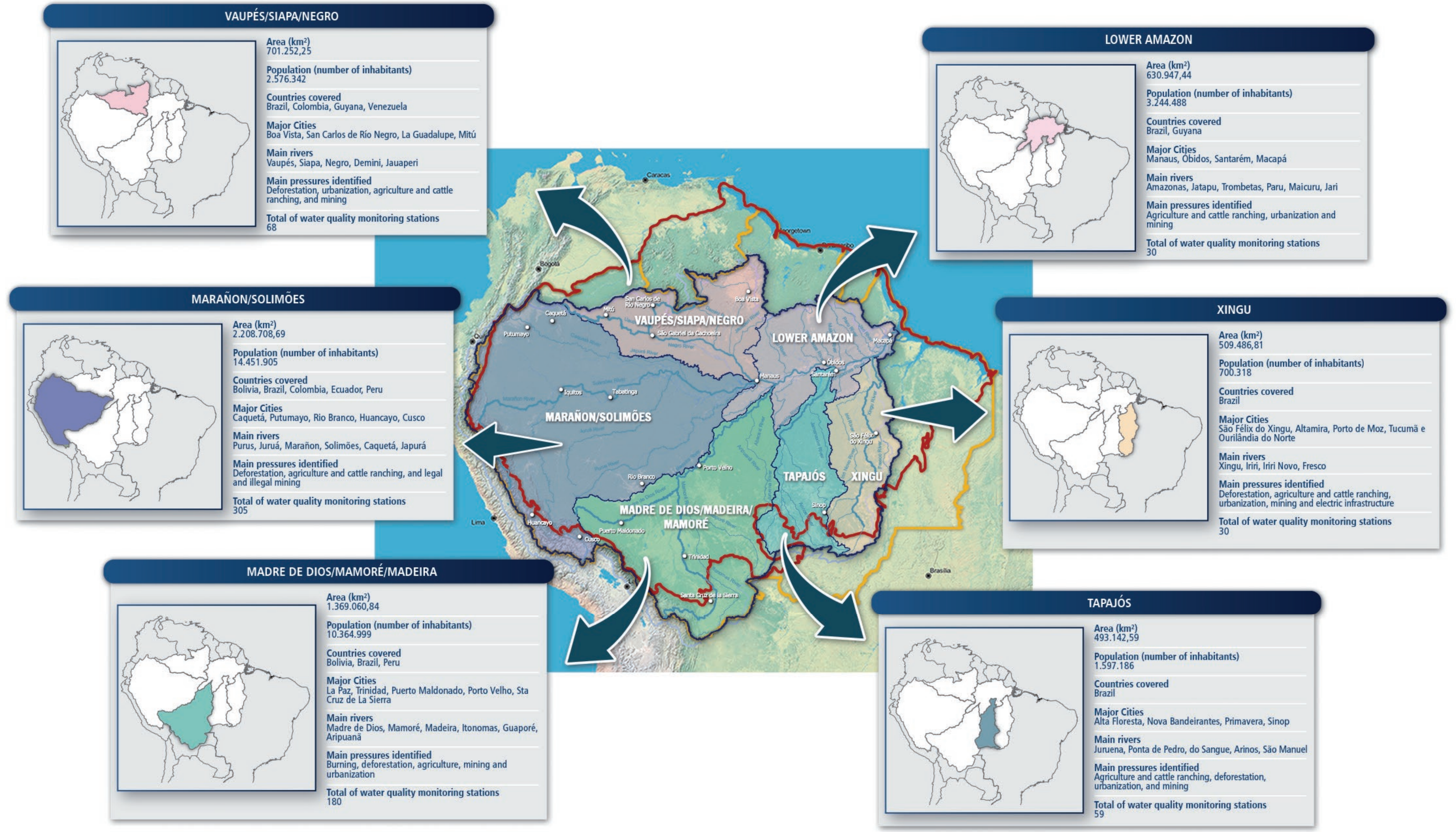


The hydrographic base used in this study was extracted from the ottobasins base (ANA, 2017) using a filter that selected only the area of the Amazon Basin, totaling 129,705 ottobasins.

To simplify the required analyses, they were grouped based on the largest tributaries of the main channel of the Amazon River, which resulted in six sub-basins: Lower Amazon, Madre de Dios/Madeira/Mamoré, Marañon/Solimões, Tapajós, Vaupés/Siapa/ Negro and Xingu.

These sub-basins and their main characteristics are presented in Figure 3. It is worth highlighting that the Amazonian watershed used in this study has a hydrological character (in blue), which differs from that used by RAISG to delimit the Amazonian Biome[1] (in red), as well as from the limit used by ACTO in the Strategic Action Program[2] (SAP) (in yellow), all represented in Figure 3.

Figure 3. Sub-basins - Division and characteristics



Source: Data from the IBGE administrative base (2016) and the ANA ottocoded base (2017), processed by Cobrape.

[1] Red Amazónica de Información Socioambiental Georreferenciada, RAISG. Available at: https://geo.socioambiental.org/arcgis/services/raisg/raisg_base/MapServer/WMSServer?request=GeACTpabilities&service=WMS.
[2] Strategic Action Program: Regional Strategy for the Integrated Management of the Water Resources of the Amazon Basin (SAP) of ACTO.

2. GENERAL CHARACTERISATION OF THE BASIN

Meeting of the waters of the Negro and Solimões Rivers | Manaus - Brazil | Adobe Stock Image Bank

2.1. USE AND OCCUPATION OF THE AMAZONIAN SOIL

The occupation of the Amazon began around 14,000 years ago, when groups of Asians arrived in the Amazon River valley. More complex indigenous societies emerged as soon as these populations developed agricultural activities and shared the same spaces. This way of life would only be altered much later with the arrival of the Europeans. At that time, they carried out adaptive forest management, extracting all the natural resources necessary for their progress and continuity (VERÍSSIMO, 2014).

When Europeans arrived at the Amazon River, they faced a dense forest inhabited by Indigenous Peoples of diverse cultures who benefited from the forest to support a reasonably large population (VERÍSSIMO, 2014). Cunha *et al.* (2006) indicate that before European colonization the Amazonian Indigenous population was around seven million inhabitants. Despite such significant number, this population managed to extract all their subsistence from the forest, causing low impact on the soil, mainly due to the cultivation method, which used the so-called relay of land, allowing time for natural revegetation, providing an anthropogenic soil of greater fertility, entitled "black Indian land."

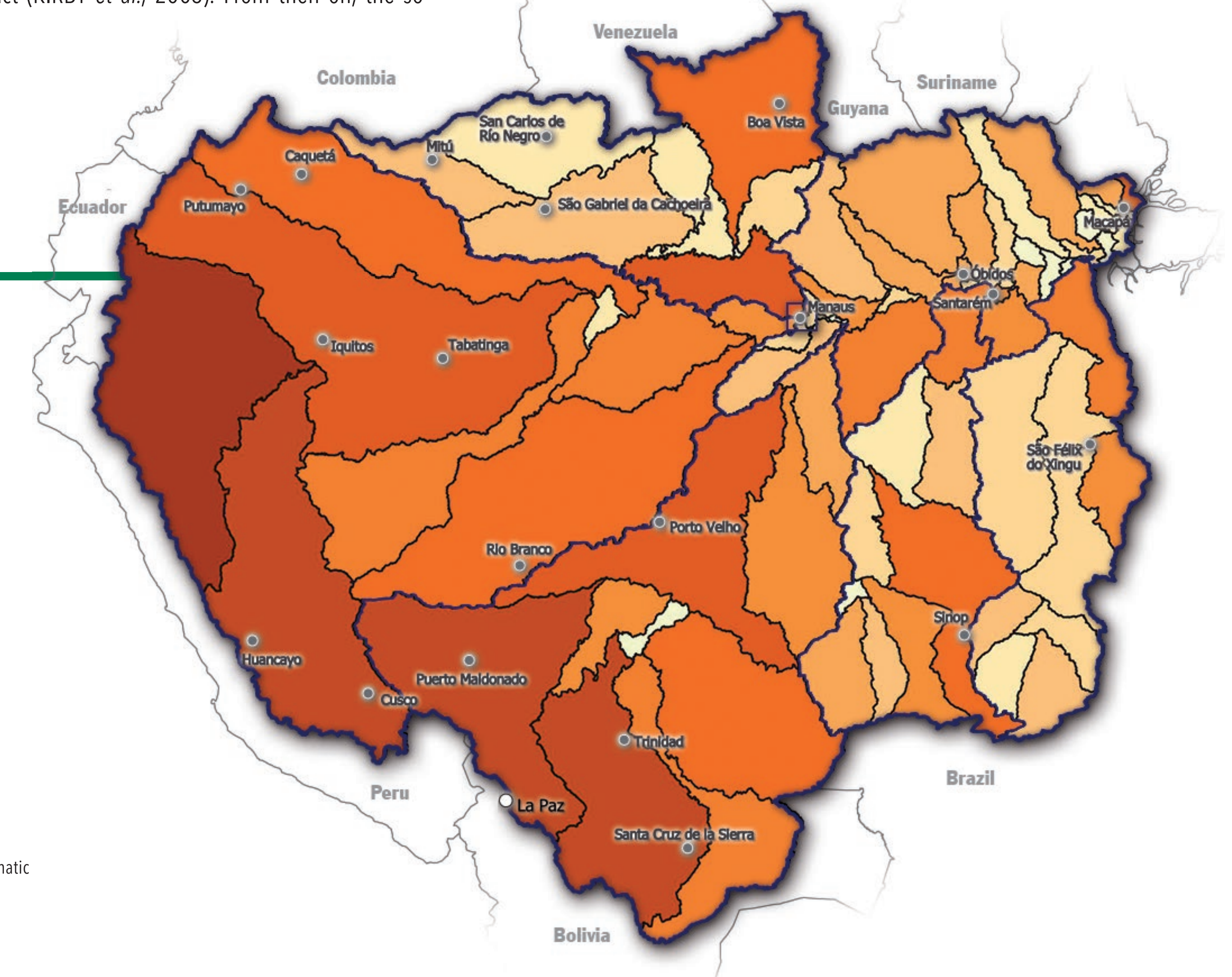
Subsequently, during the 17th and 18th centuries, characterized by the colonization phase, there was a significant decrease in the number of Amazonian native Indigenous Peoples.

However, as the access to the dense forest was difficult and limited to waterways, land use and exploitation remained low impact (KIRBY *et al.*, 2005). From then on, the so-called "colonial occupation" was consolidated, encompassing cities such as La Paz, Cusco, Putumayo, and riverine municipalities settled in more interior regions of the forest, such as Manaus, Iquitos, and Trinidad, in a not very condensed form (MOYA, 2018; WORLD BANK, 2021).

As a consequence, and already being in the 19th century, the population configuration of the Amazon region was primarily composed of mixed individuals (Indigenous, white, and black people), which led to changes in land use and occupation, with the collection of natural products and replacement of agriculture by the rubber economic cycle (IMAZON, 2021).

Despite the economic rubber cycle in Brazil, which took place between the end of the 19th and the 1940s, exploitation of Amazonian land was only accentuated from the second half of the 20th (AB'SABER, 2002). According to Veríssimo (2014), the period was characterized by the devastation of the forest, with significant changes in the landscape, especially as a result of the opening of roads that paved the way for pastures and predatory logging, especially in the Brazilian Amazon. In this period, in addition to these pressures, other activities were intensified, such as mining, hydroelectric dams, and oil lots, now including the other countries.

Figure 4. Population in the Amazon Basin



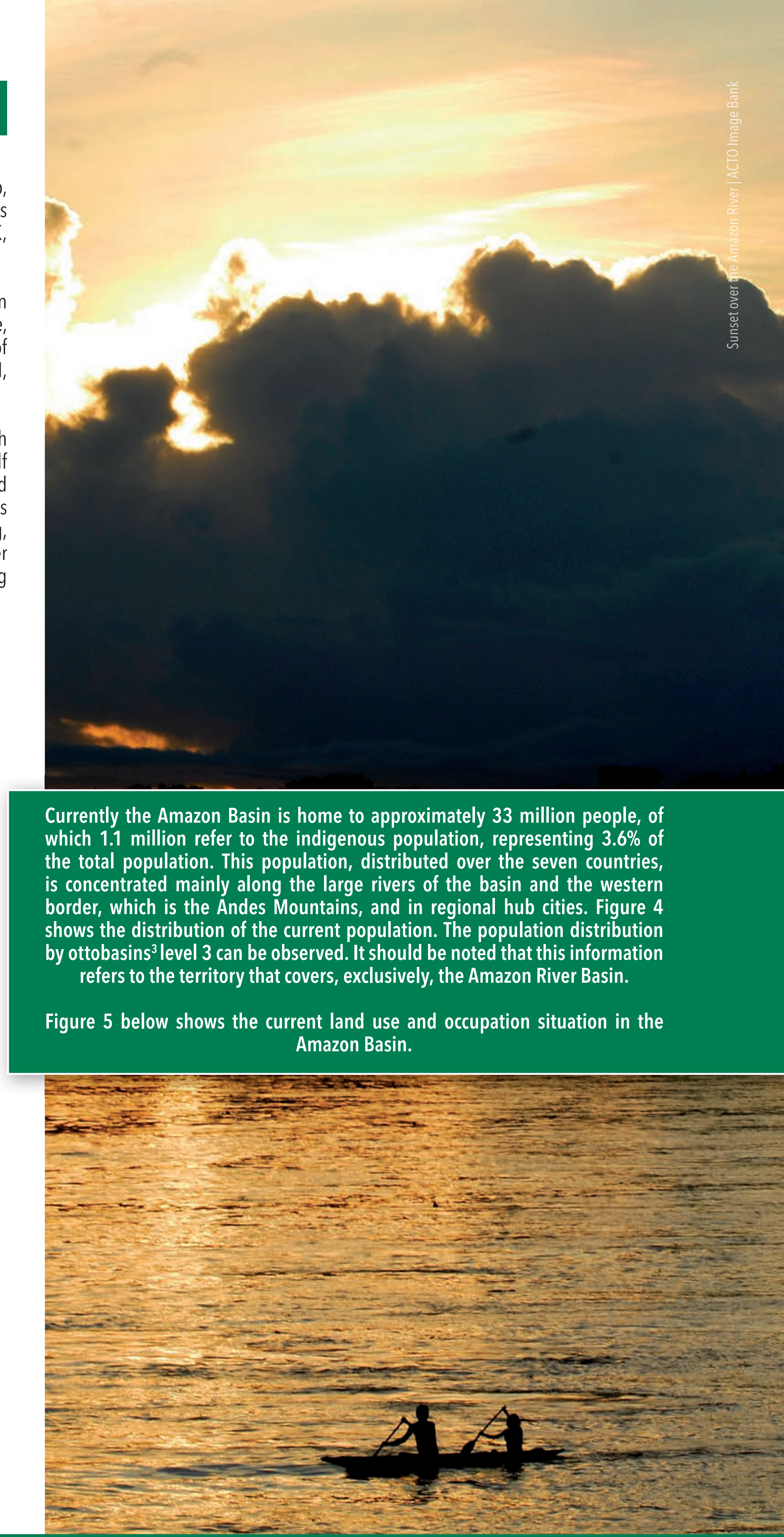
Legend

Absolute Population Range (Number of Habitants)

- Up to 10.000
- 10.001 - 25.000
- 25.001 - 50.000
- 50.001 - 75.000
- 75.0001 - 100.000
- 100.001 - 250.000
- 250.001 - 500.000
- 500.001 - 1.000.000
- 1.000.001 - 2.500.000
- 2.500.001 - 5.000.000
- Above 5.000.000

Source: Adapted from IBGE (2020) and Atlas of Hydroclimatic Vulnerability of the Amazon Basin OTCA (2021).

[3] Based on the drainage area and hydric topology, Pfafstetter (1989) elaborated a methodological proposal for the hierarchical codification of hydrographic basins. The basins are treated as areas of contribution of the stretches of the numerically codified hydrographic network and considered the main input of the areas of the direct contribution of each stretch of this same hydrographic network. The details of the methodology are presented in Product 3.

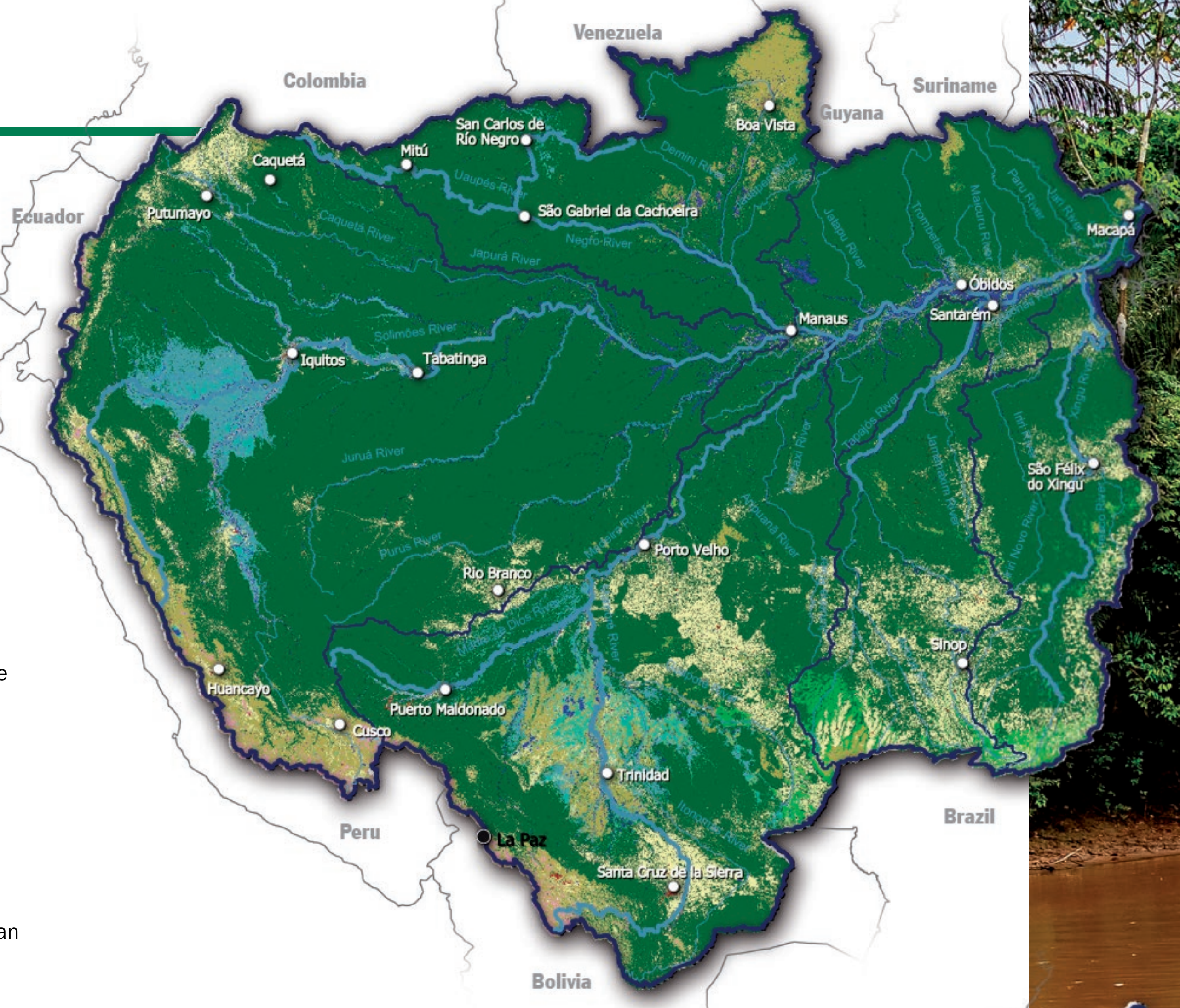


Sunset over the Amazon River | ACTO Image Bank

Currently the Amazon Basin is home to approximately 33 million people, of which 1.1 million refer to the indigenous population, representing 3.6% of the total population. This population, distributed over the seven countries, is concentrated mainly along the large rivers of the basin and the western border, which is the Andes Mountains, and in regional hub cities. Figure 4 shows the distribution of the current population. The population distribution by ottobasins[3] level 3 can be observed. It should be noted that this information refers to the territory that covers, exclusively, the Amazon River Basin.

Figure 5 below shows the current land use and occupation situation in the Amazon Basin.

Figure 5. Land use in the Amazon Basin



Source: Adapted from Mapbiomas (2020).

2.2. NATURAL PROTECTED AREAS AND INDIGENOUS LANDS

The Amazon is an emblematic and internationally known region. Before its exploitation started, it was an isolated area with severely restricted access, which was only by river (KIRBY *et al.*, 2005). Since then to the present waterway transport has been the main means of transportation in the region.

Subsequently, together with the beginning of the exploitation of natural resources there was greater pressure for preservation, mainly to avoid the large-scale fires that were taking place. To this end, several protection areas were requested and/or declared, such as the Natural Protected Areas (NPAs) and the Indigenous Lands (TIs). (Figure 6)

The Natural Protected Areas account for 1,349,169 km², while the Indigenous Lands occupy 1,804,174 km², representing 22.82% and 30.51% of the total area of the Amazon Basin. The region has about 395 NPAs and about 3,610 Indigenous territories distributed among 305 ethnic groups, which suffer the negative effects from the exploitation of the basin.

Both the Natural Protected Areas and the Indigenous Lands play a fundamental role in environmental preservation involving the conservation of water resources, conservation of forests and biodiversity, and reduction in the effects of climate change, among others. The indigenous people have always been characterized by the use and adequate management of natural resources without compromising the ecosystems, and this practice has proven to be of the utmost importance for the conservation of biodiversity. It is beyond dispute that indigenous people's knowledge brings several insights for sustainability as a whole, such as the rational use of the soil, refraining from hunting more than necessary, and no depletion of water resources, either quantitatively or qualitatively.

Cuyabeno - Ecuador | Adobe Stock Image Bank

Figure 6. Natural Protected Areas and Indigenous Lands in the Amazon Basin

Source: RAISG (2020) data processed by Cobrape. See table of sources on page 45, items 1 and 2.

2.3. FLOOD AREAS

The Amazon region is naturally characterized by various floodable areas (Figure 7). In ecological terms, floodable areas periodically receive lateral contributions of water, whether from rivers, lakes or through the underground contribution or precipitation. In the case of the Amazon region, the floodable areas affected by rivers and lakes are of greatest interest (SOARES *et al.*, 1999).

Millions of years ago, nearly 25% of the Amazon region was transformed into an aquatic ecosystem by the dynamics of flood–pulses, which is a natural process that enriches the soil with the sediments that are dragged from the various Andean basins to the lowlands. The process has been life-defining for indigenous cultures as floods contribute to the abundance and high diversity of aquatic species, especially fish and birds that migrate from distant areas to the flooded sites that become a rich source of food. Thus, this flood period is a fundamental for the consolidation of the food chain, sustaining the biodiversity that is the basis for life maintenance of Indigenous Peoples (RAISG, 2020).

It is worth stressing that, due to their specificities, floodable areas quickly recycle organic matter and nutrients, thus making the soil fertile to conduct socioeconomic activities, implying higher productivity indicators if compared to dry areas (SOARES *et al.*, 1999). On the other hand, these areas, when preserved, are extremely important water quality assurance and for the local biodiversity, for they are habitats for several species of fauna and flora. This dichotomy makes floodable areas the scene for various conflicts in land use, occupation, and the exploitation of water resources.

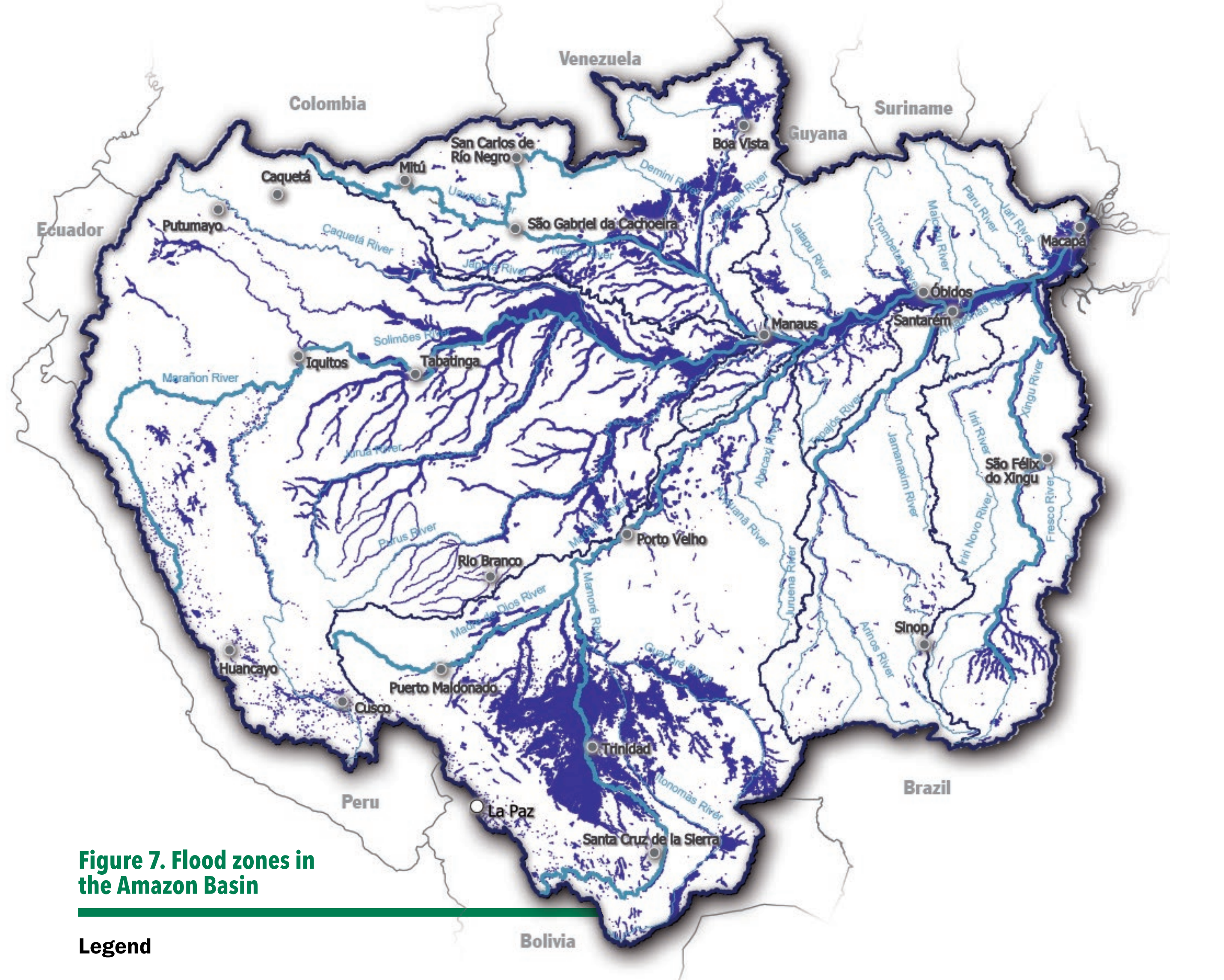


Figure 7. Flood zones in the Amazon Basin

Source: Adapted from OTCA (2021).

Nanay River | Peru | ACTO Image Bank

Mexiana Island | Pará - Brazil (2010) | Rui Faquini/Ana's Image Bank

ICAO Image Bank

2.4. HYDROGEOCHEMICAL CLASSIFICATION OF AMAZON RIVERS: CLEAR, WHITE AND BLACK WATERS

The Amazonian rivers have different hydrogeochemical characteristics in terms of pH, conductivity, mineral salts, suspended solids, organic substances, and color, reflecting the different regions they cross. The Amazon rivers have been divided into three main categories according to the relationship between geology, vegetation, and their characteristics: clear, white and black water rivers. These three categories can be visualized in the images below, in which the color difference is evident.

Clear, white and black waters

Source: Portal Amazônia (2019).

The **clear waters** originate from ancient geological formations, and the plains flooded by them are called igapós (SANTOS, 2012; ZEIDEMANN, [s.d.]), their coloration is clear, transparent, from yellowish-green to olive. These are the most transparent waters, with pH ranging from acidic to basic and intermediate electrical conductivity if compared to the other categories.

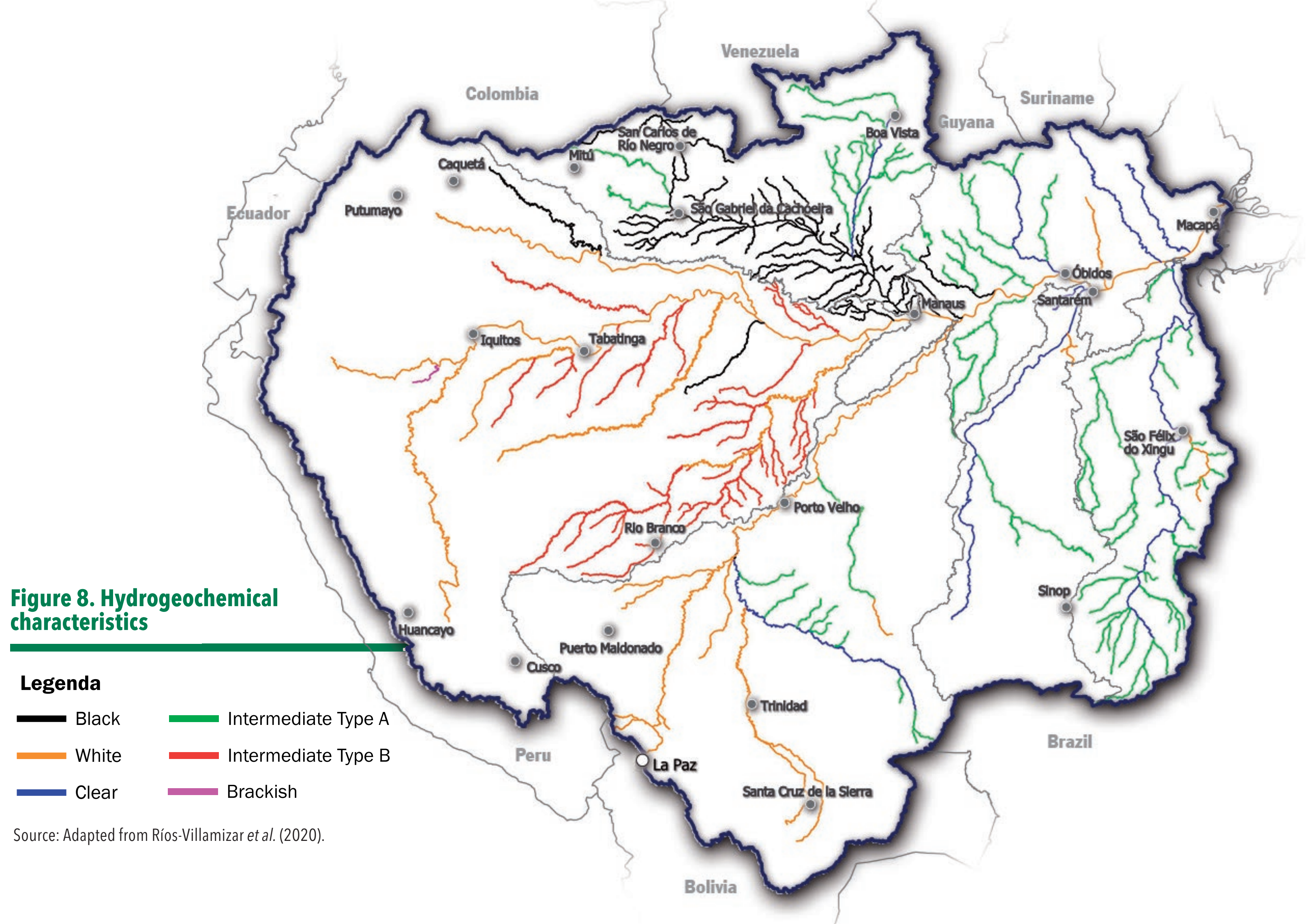
White-water rivers have their headwaters in the Andes and deposit sediments in the so-called várzeas (SANTOS, 2012; SIOLI & KLINGE, 1962), their waters are yellowish, ochre, and turbid. They have low transparency, neutral pH, and high electrical conductivity.

The **black waters** come from the drainage of sandy soils covered by vegetation known as campina, campinarana, or Amazonian caatingas, their floodplains are of low fertility and are covered by flooded forest (SANTOS, 2012; ZEIDE- MANN, [s.d.]). The waters are brown, brownish to reddish in hue. These waters have intermediate transparency, a more acidic pH, and low conductivity.

A study by Rios-Villamizar *et al.* (2020) suggested the inclusion of waters of intermediate characteristics in addition to the three main categories, especially in the lower order tributaries, as can be seen in the following figure. These stretches represent rivers with many transitional hydrochemical stages and strong influence of rainfall seasonality.

The Type A Intermediate Water rivers have clear waters and flow through different geological formations from Guyana to central Brazil. The Intermediate Water rivers of Type B drain waters in stretches of Andean origin and present hydrogeochemical characteristics such as those observed for the white and black waters. There are also some rivers with brackish characteristics that are located in regions of marine influence or that have greater salinity owing to high concentrations of sodium and chloride, such as those near the Marañon River. The hydrogeochemical characteristics cited are represented in Figure 8.

Figure 8. Hydrogeochemical characteristics



Source: Adapted from Rios-Villamizar *et al.* (2020).

3. PRESSURES ON SURFACE WATER QUALITY

Based on the survey of secondary data to perform a homogeneous and integrated analysis of human activities with potential impact on water quality in the Amazon Basin, the pressures defined were deforestation, fires, mining, agriculture and cattle-raising, hydroelectric power plants, oil exploration, domestic sewage, solid waste and climate change.

These pressures were analyzed integrally with the water quality monitoring data carried out by the countries, in order to identify the pressures causing changes in theirstate or to identify areas with unmonitored pressures. The integrated analysis allowed for a more accurate verification of the geo-referenced information to pinpoint the most impacting sources of pollution and facilitate the identification of studies and good practices that could be related to that region or pressure.

These pressures are presented below and were grouped for the Amazon Basin as a whole, however, always highlighting the sub-basins where they are located.

These pressures corroborate the main causes of water contamination in the Amazon Basin laid out in the Transboundary Diagnostic Analysis (ACTO, 2018), citing mining activities, domestic and industrial wastewater, river transport, among others.

Amazon Forest | Brazil | Adobe Stock Image Bank

3.1. DEFORESTATION

Deforestation in the Amazon Basin is one of the oldest pressures faced by the region and it is related to several causes: the expansion of human settlements and the several types of natural resources exploitation. In some countries deforestation is caused by cultivation for illegal use and illegal extraction of minerals, as well as the construction of unplanned infrastructure, fires, logging, farming and livestock, and the installation of hydroelectric power plants. The main effect of deforestation is related to water bodies sedimentation, since, without the forest, surface runoff quickly carries the sediments to the rivers. In this process, several substances are washed away with the sediments, including toxic substances, which are heavily deposited in the hydric body favouring alterations in the water quality.

Figure 9 illustrates the deforestation regions identified between 2001 and 2018. As shown, in the whole basin there are significant areas with occurrence of highly deforested region in the headwaters located between Peru and Colombia, in the Marañon/Solimões sub-basin. In this sub-basin, deforestation is mainly linked to mining, by wells and alluvial deposits, and agricultural and livestock activities. The figure also highlights a region near Santa Cruz de la Sierra, in Bolivia, in addition to the entire southeastern region of the basin located in Brazil, where the so-called "Arc of deforestation" is located. In this region, the agricultural frontier advances towards the forest and presents nearly 75% of Amazon deforestation (OVIEDO; LIMA; AUGUSTO, 2020). However, according to the authors, this territory covers 256 municipalities, from the west of the state of Maranhão and south of Pará towards the west, passing through Mato Grosso, Rondônia and Acre.

In this region of intense deforestation, the Tapajós sub-basin stands out as the one most impacted by this pressure, especially in the region near the São Manuel or Teles Pires River, characterized by the presence of floodable zones. The wood resulting from deforestation in this sub-basin is burned or sold and the deforested areas are mostly occupied by agriculture and cattle ranching. The same occurs in the Xingu sub-basin - part of the "Arc of deforestation" - where these areas are occupied by mining and infrastructures form the electricity sector.

In the Vaupés/Siapa/Negro sub-basin, deforestation occurs most intensely in the district of Calamar and the surroundings of MitÚ (Colombia), and in the Brazilian regions, it occurs around Boa Vista; near the Upper Rio Negro indigenous land, on the Padauari River, in the municipality of Barcelos; and on the Catrimani River, which runs through the municipalities of Iracema and Caracaraí. The most prominent areas in the Madre de Dios/Madeira/Mamoré sub-basin are the areas around Porto Velho (Brazil) and Santa Cruz de La Sierra (Bolivia), affected directly by agriculture and cattle ranching.

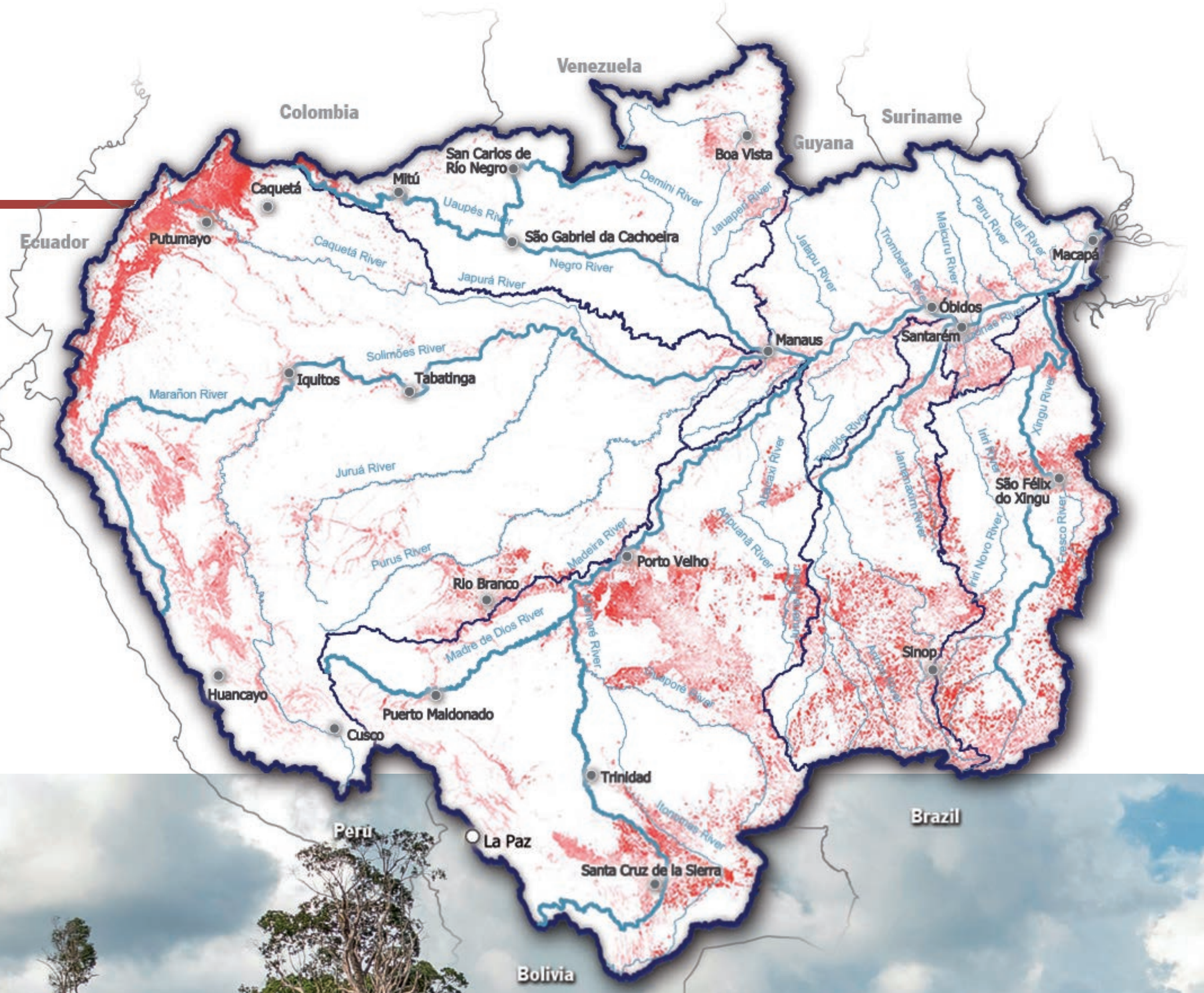
The Centre for Nuclear Energy in Agriculture (Cena) concluded that the impacts of deforestation in the Amazon Basin are causing in the environment a chain reaction. Some rivers in the Ji-Paraná Basin have reached levels of dissolved materials similar to contaminated watercourses in the interior of São Paulo (FAPESP, 2002).

Figure 9. Deforestation in the Amazon Basin from 2001 to 2020

Legend

Deforestation

Source: RAISG (2020) data processed by Cobrape. See table of sources on page 45, item 3.

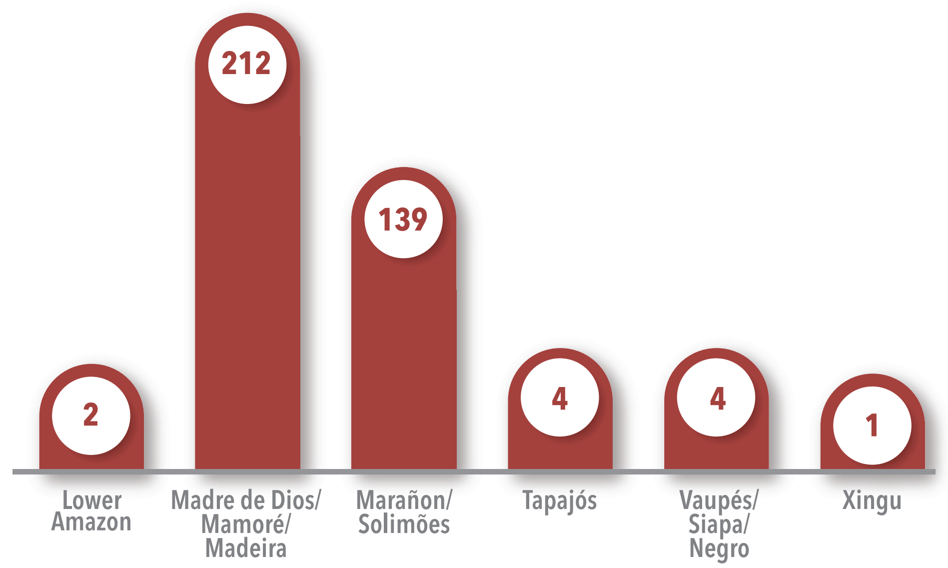


3.2. FOREST FIRES

Although forest fires is a very old practice that has also been adopted by the native Amazonian peoples, the purpose of this practice differs, especially in terms of the intensity of the burnings. The native peoples used to burn as a way to "clean" small territories, without harming the trees, and planted their crops in between them. Therefore, the charcoal produced served as fertilizer, which in smaller proportions without jeopardizing water quality (National Geographic, 2020).

On the other hand, when wildfires are carried out on a large scale, Embrapa (2019) analyzes that, although ashes are rich in nutrients for agricultural activities (calcium, phosphorus, magnesium, and nitrogen), they result in consequences for water bodies, such as reduced dissolved oxygen in stagnant water environments, increased pH, and generate toxicity for aquatic species.

Figure 10. Total number of fires per sub-basin (October 24 and 25, 2021)



The National Institute for Space Research (INPE) of Brazil monitors fires via satellite in almost real time, identifying the outbreaks of fires in the last 24 hours. Data has shown a significant increase in the number of fires in the Amazon, relating this fact to the decrease in rainfall in the south portion of South America.

In parallel, ACTO is also performing real-time monitoring of fires through the Amazon Regional Obervatory, along with data provided by INPE, and the Operational and Management Centre of the Amazon Protection System (Censipam), which will serve as a tool for the 8 Member Countries.

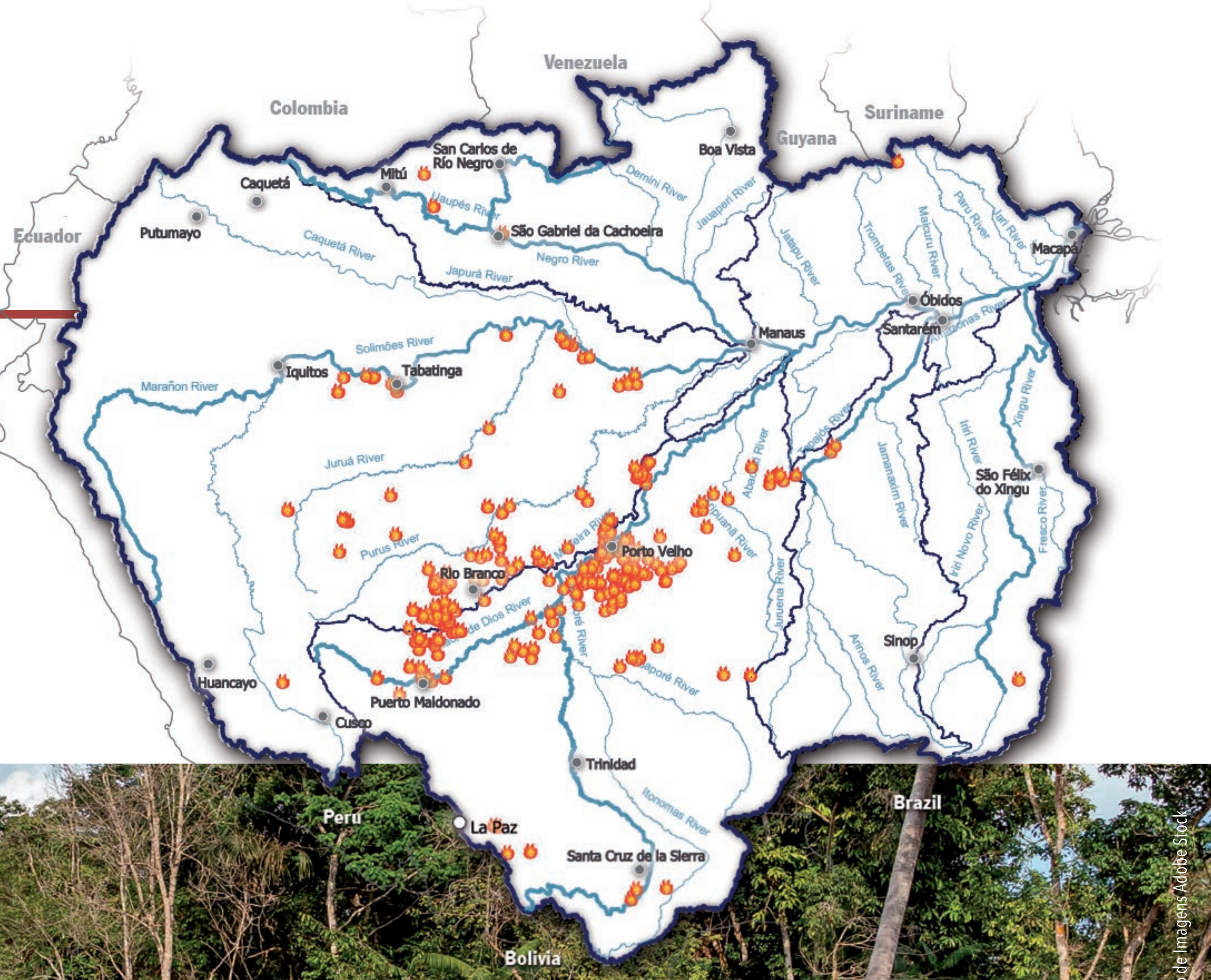
Figures 10 and 11 show the data from the INPE system resulting from the AQUA M-T satellite (Morning and Afternoon), monitored between 24 and 25 October 2021, in which it is possible to verify that the greatest concentrations of fires are located in Brazil, Bolivia and Peru. It is possible to affirm by the constant observation of these data that this panorama is recurrent and that the Madre de Diós/Madeira/Mamoré and Marañon/Solimões sub-basins have the greatest number of fires.

Figure 11. Fire outbreaks identified by satellite in the Amazon Basin between 24 and 25 October 2021

Legend

Fire outbreaks identified by satellite AQUA M-T (INPE)

Source: Adapted from INPE (2021) - Data from the AQUA M-T satellite.



3.3. MINING

The mining sector is a significant pressure on water quality as water bodies are affected by polluting substances such as oils, grease, silt, clay and heavy metals, including mercury.

Heavy metals are of particular concern in relation to public health due to their cumulative nature, as their concentration increases along the trophic chain. In addition to the effects on public health, there are direct impacts on water resources, such as changes in pH and electrical conductivity that, in turn, can alter the balance of other physical and chemical components of water. In this sense, illegal mining stands out affecting negatively the entire local ecosystem, resulting in other direct damage to water quality.

There are several mining operations in the Amazon Basin that are granted (exploration or exploitation[4]) and requested, as shown in Figure 12, which also depicts the occurrence of several illegal mines. Thus, mining, especially illegal, is a strong pressure on the water quality of the Amazonian rivers and is present in all the sub-basins.

Although the mines granted in the basin exploit various types of minerals, the most common is gold, which requires the use of mercury for extraction. In the case of illegal mining, major contamination has occurred since the mining process is carried out directly in the waters, without any type of containment.

Assessing the impact of mercury solely through its concentration in water is unrepresentative. It is essential to consider the concentrations in the human population and aquatic biota, where low concentrations can mean severe damage.

Damage is caused by the consumption of fish, which are the dietary basis of a large Amazonian population contingent, that are highly contaminated by mercury. Indirect consumption of mercury through contaminated fish can cause accumulation in the body, affecting mainly kidneys, liver, digestive and nervous system, interfering with the functioning of the body as a whole.

Diniz *et al.* (2022) point out that through satellite images, it was possible to identify the increase in the turbidity of the waters of the Tapajós River, considering the complex hydrological system of the Amazon Basin and the influence of mining activity.

Gold mining area in the Amazon Forest | Pará - Brazil | Adobe Stock Image Bank

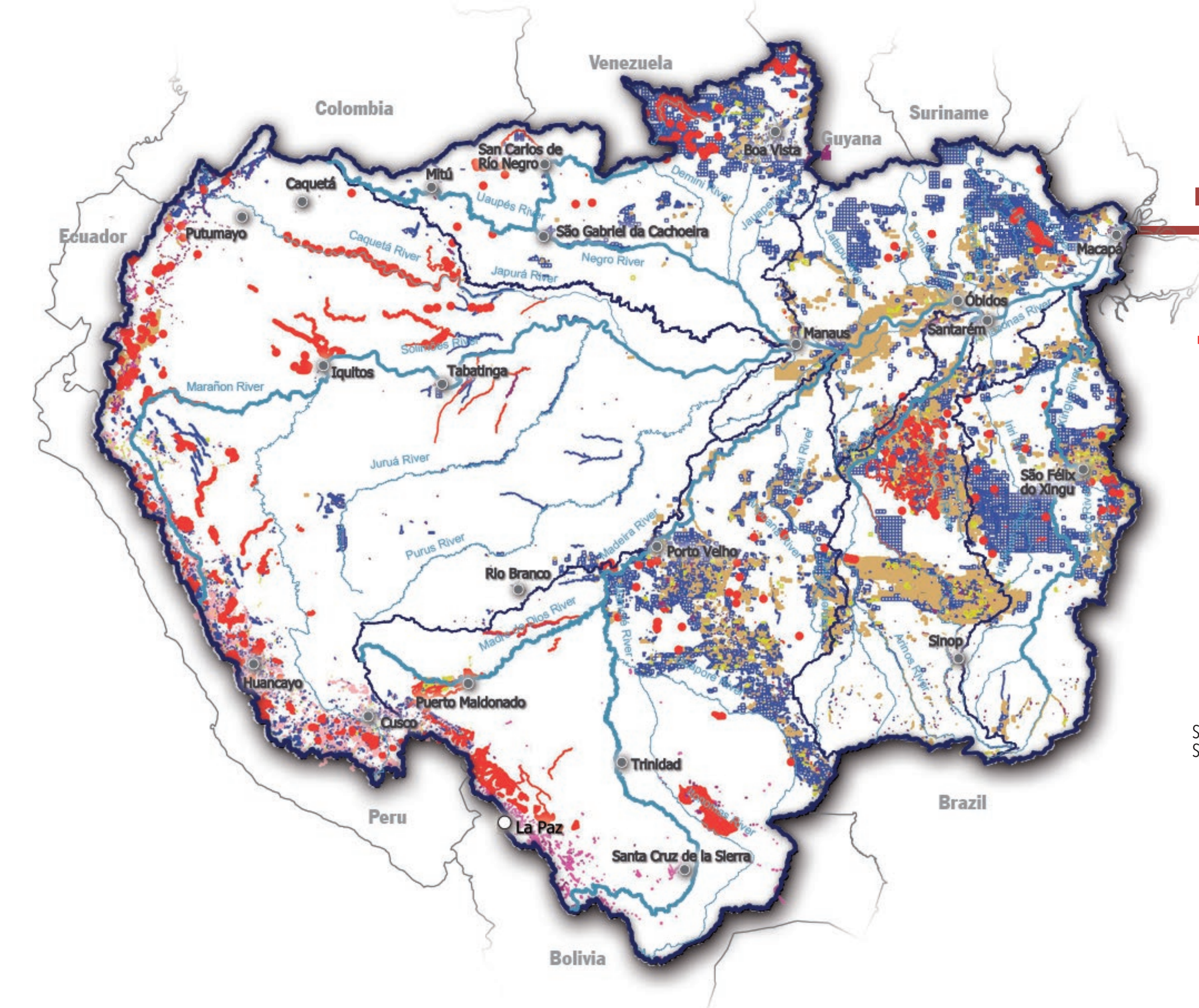


Figure 12. Mining operations in the Amazon Basin

Legend

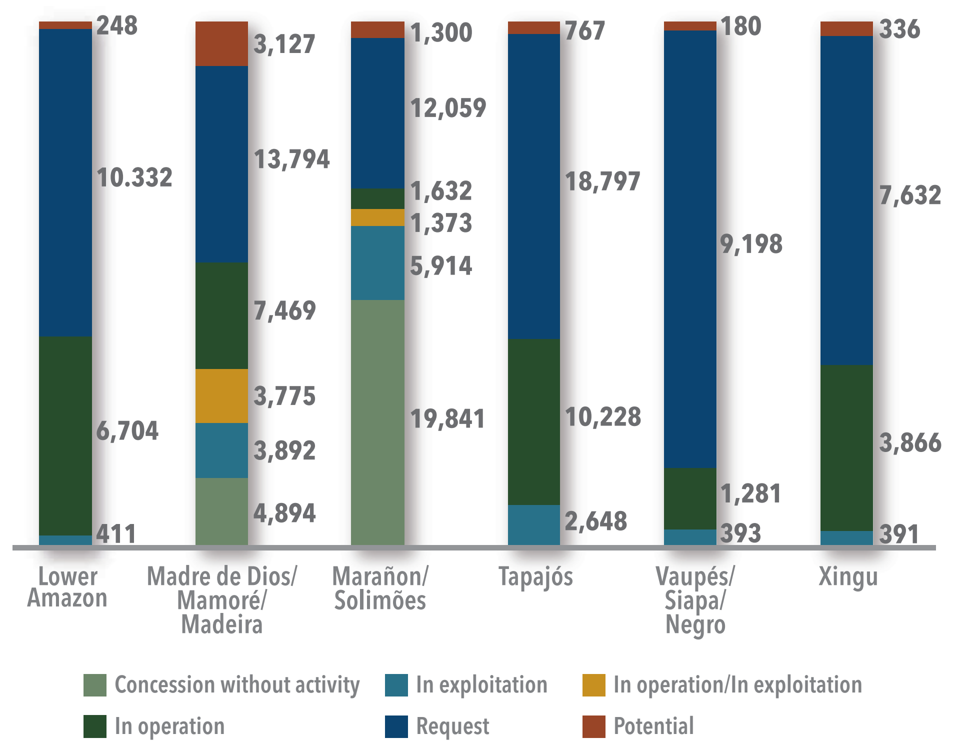
- Localities with illegal mining practice
- Rivers with permanent illegal mining activity
- Areas with illegal mining

Situation of the mines

- Concession without activity
- Under exploitation
- In operation/in exploitation
- In exploitation
- Request
- Potential

Source: RAISG (2020) data processed by Cobrape. See table of sources on page 45, items 4 and 5.

Figure 13. Number of mining operations per sub-basin



[4] Exploration mines are those granted for research purposes, without the removal of material, to analyze whether or not a given resource exists, its feasibility for exploitation, ore studies and other similar purposes. The exploitation mining, on the other hand, means that there is the removal of natural resources. Note that some mines are granted for both cases, both for exploration and exploitation.

3.4. AGRICULTURE AND LIVESTOCK

Agricultural activities are a type of pressure that significantly impacts water quality, but differently according to the activity, as agriculture is more associated with diffuse pollution, while livestock farming is both diffuse and point source.

Diffuse pollution from agriculture involves carriage of pesticides and fertilizers into the water, which increases the concentrations of nutrients such as nitrogen and phosphorus, as well as other substances. Furthermore, by devastating the natural vegetated area, it favours the carriage of sediments and the silting up of rivers, as commented.

Livestock farming, in turn, impacts surface water bodies directly, when it comes to the crossing of animals by streams, and indirectly, by carrying animal waste (EMBRAPA, 2011).

Agricultural and livestock activities in Amazonian territories are widely spread. In Brazil, they are evident in the states of Rondônia, Mato Grosso, and Pará; in Bolivia, in the departments of Beni, Santa Cruz, and Cochabamba; in Colombia, mainly in the departments of Putumayo and Caquetá; and in Ecuadorian and Peruvian territories, in the departments that border the headwaters of the Marañon/Solimões sub-basin.

The survey of agricultural and livestock activities presented by RAISG (2020) and represented in Figures 14 and 15 was elaborated on a larger scale, allowing for a macro view. Agriculture and livestock activities were identified separately, complementing the land use analysis, and demonstrating that these activities continue to advance significantly in forest areas.

As mentioned, the Marañon/Solimões sub-basin stands out for agricultural and livestock pressure in its western portion, coinciding with the headwaters in the Andean region; around Rio Branco (Brazil), at the triple border between Brazil, Colombia, and Peru; as well as in San Juan Bautista, south of Iquitos, in the Maynas district (Peru).

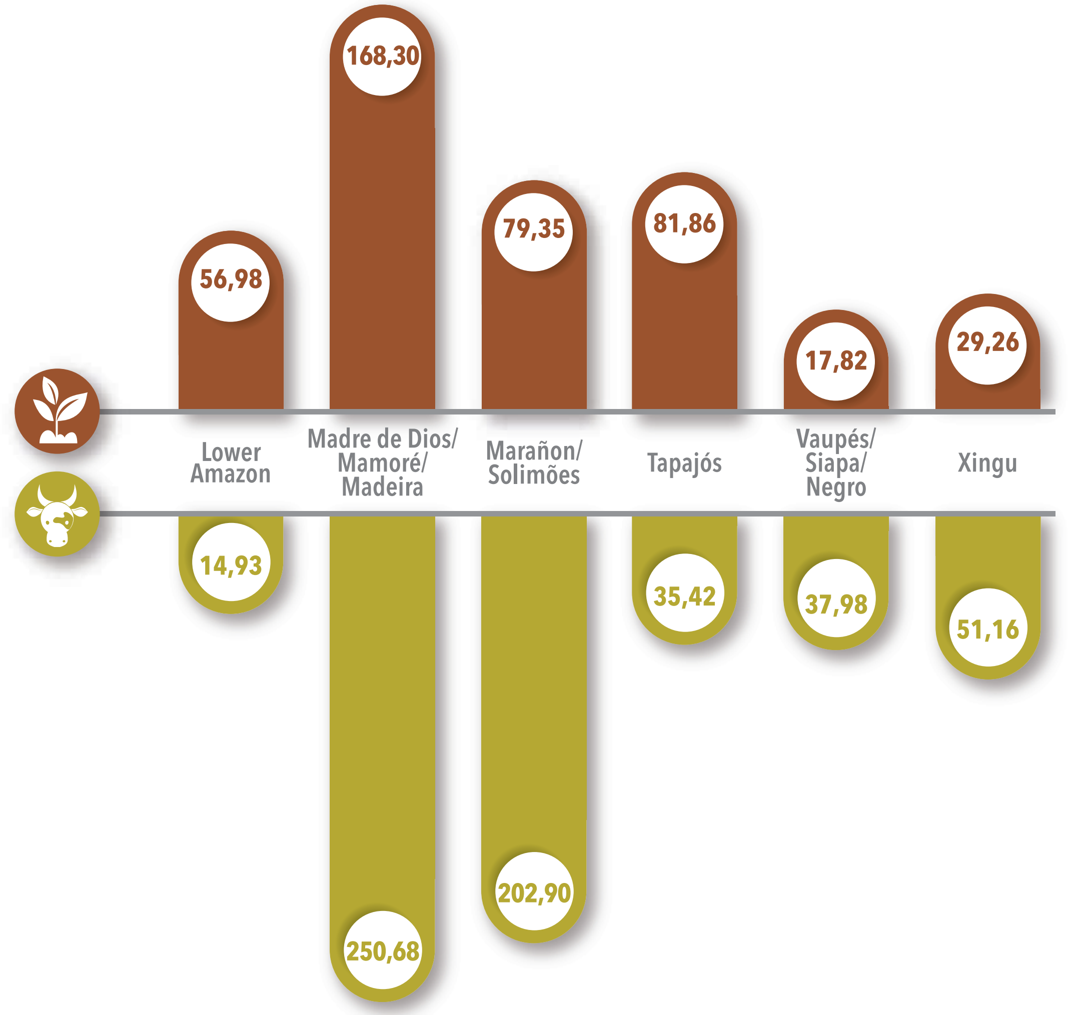
In the Vaupés/Siapa/Negro sub-basin, regions that are most affected by this pressure have been observed: in the far west in Calamar and Miraflores (Colombia); in the surroundings of Boa Vista (Brazil), in the north of the sub-basin in Potaro-Siparuni (Guyana) to Rorainópolis (Brazil); and in the south in the municipalities of Manaus and Iranduba (Brazil).

In the Lower Amazon, the margin of the Amazon River from Manaus to Macapá stands out. This river is classified as hydrogeochemically white water, with a natural characteristic of an extensive flood zone on its banks, therefore, it ends up being heavily exploited by agriculture. The same occurs in the Madre de Dios/Madeira/Mamoré sub-basin, with flooded areas taken over by agricultural activity.

The Tapajós sub-basin presents a strong pressure from agriculture, especially in the southern portion, while the Xingu sub-basin presents the most pronounced livestock activity, also in the southern portion.

Soybean farms in the Amazon rainforest | Xingu Indigenous Park - Brazil | Adobe Stock Image Bank

Figure 14. Agricultural and livestock area by sub-basin (km² x 1,000)



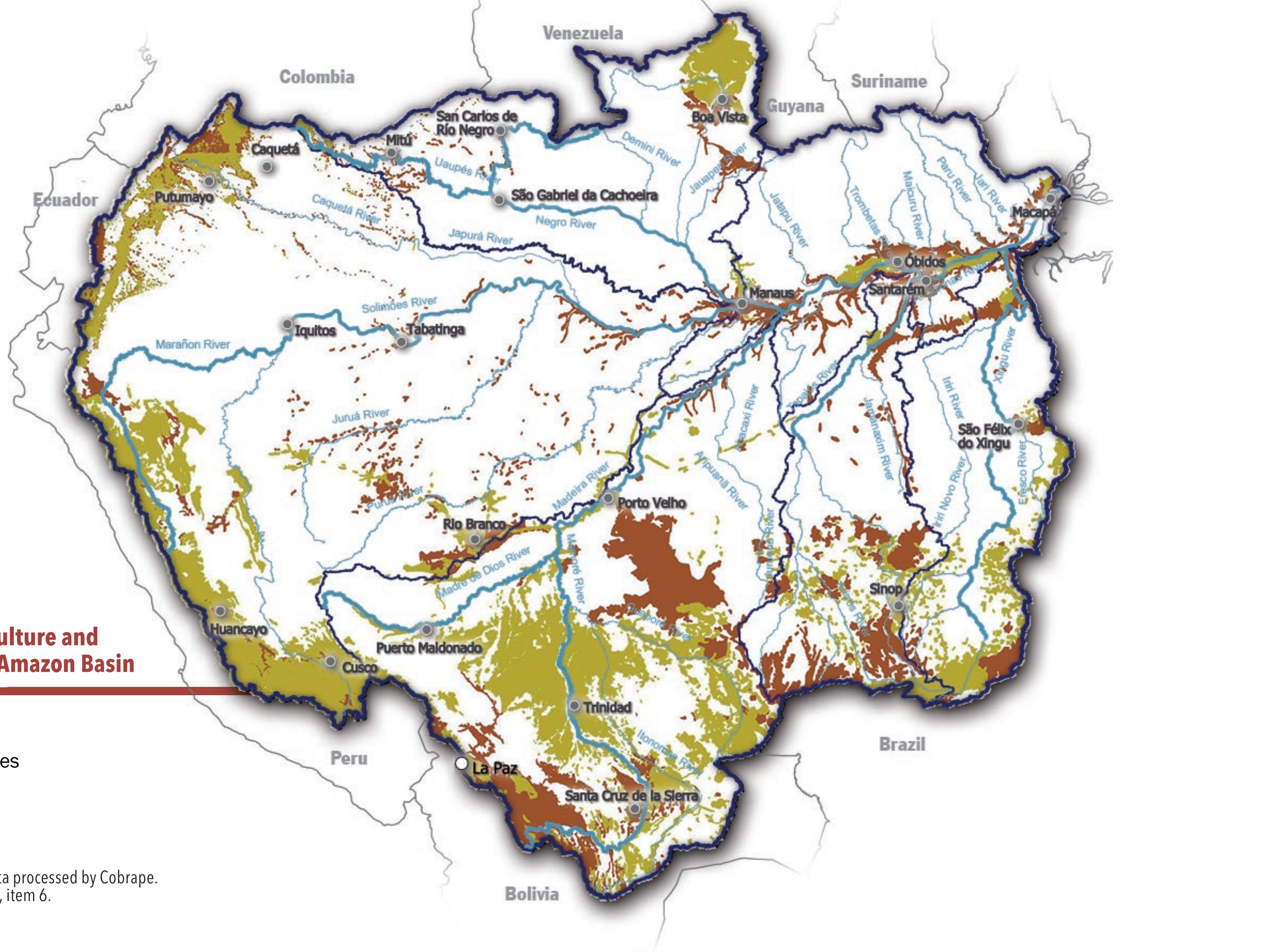


Figure 15. Agriculture and livestock in the Amazon Basin

Legend

Agricultural Activities

- Agriculture
- Livestock

Source: RAISG (2020) data processed by Cobrape. See table ces on page 45, item 6.

3.5. HYDROELECTRIC PLANTS

In the area covered by the Amazon Basin there are different types of undertakings for electric power generation, among which stand out the hydroelectric power plants which are directly related to the quality of the water.

The construction of these undertakings, usually large ones, significantly affects the surrounding region and the physical, chemical and biological alterations to the hydric resources are expressive: (i) acidification of the water when there is no previous deforestation on an adequate scale; (ii) eutrophication produced by the leaching of fertilizers in adjacent arable areas; (iii) interference in migratory and reproductive processes of the ichthyofauna; (iv) hydrological alterations downstream of the reservoir; (v) increase in the sediments accumulated both in both in the upstream and downstream river channels in as well as in the accumulation basin, potentiating erosive phenomena; (vi) increase in cases of waterborne diseases; (vii) alteration in water temperature, oxygenation (dissolved oxygen) and acidification (pH); and (viii) retention of phosphorus and export of nitrogen capable of eutrophicating downstream of the reservoir (HYNES, 1979; HENRY, 1989; HARPER, 1992; CMB, 2000; NAIME, 2012).

Figure 16 illustrates the Hydroelectric Power Plants (HPP) and Small Hydroelectric Plants (SHP) identified in the Amazon Basin, and the following chart accounts for these structures, including the planned undertakings, showing the potential growth of this activity in the basin.

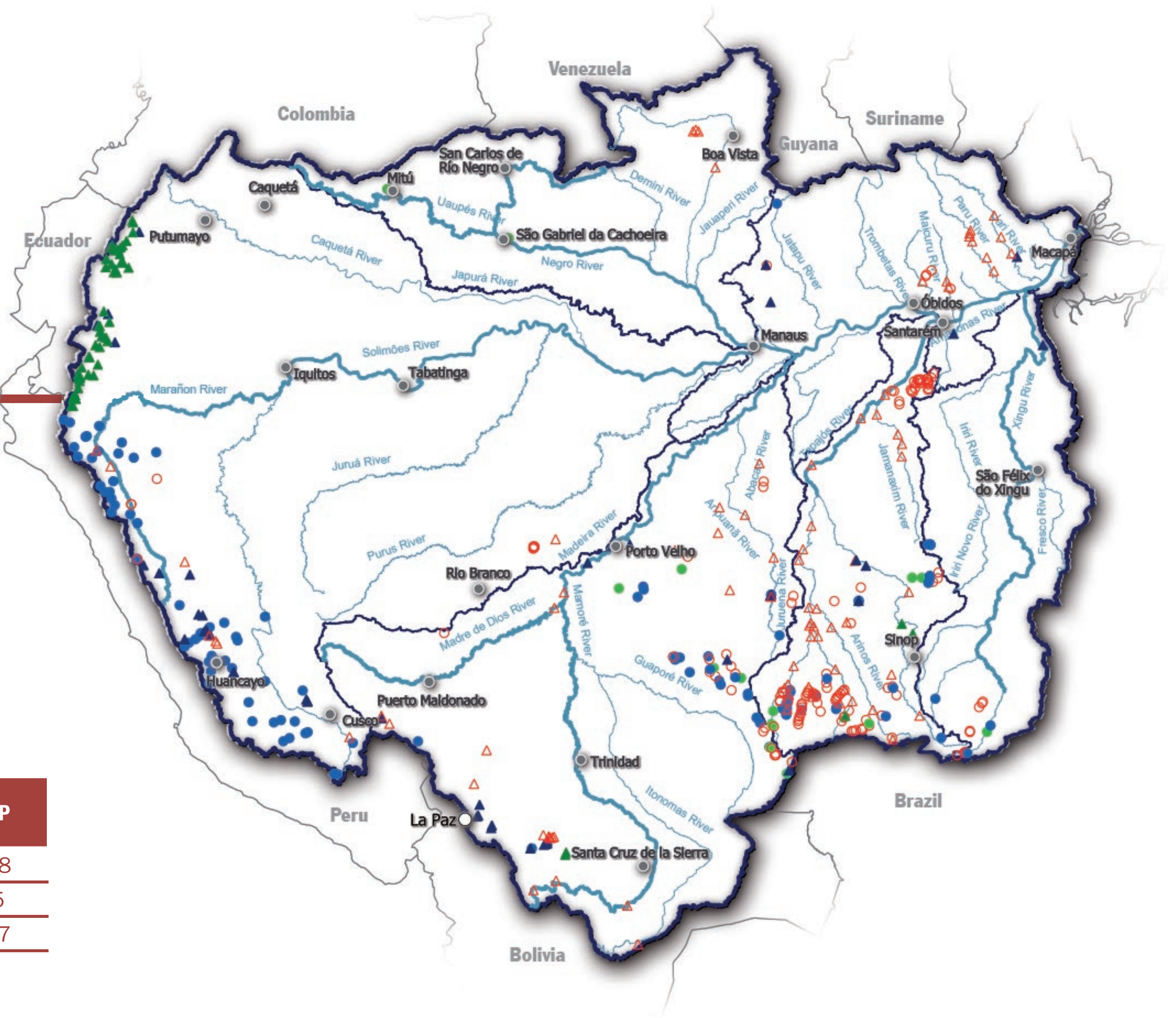


Figure 16. Hydroelectric Power Plants and Small Hydroelectric Power Plants in the ARB

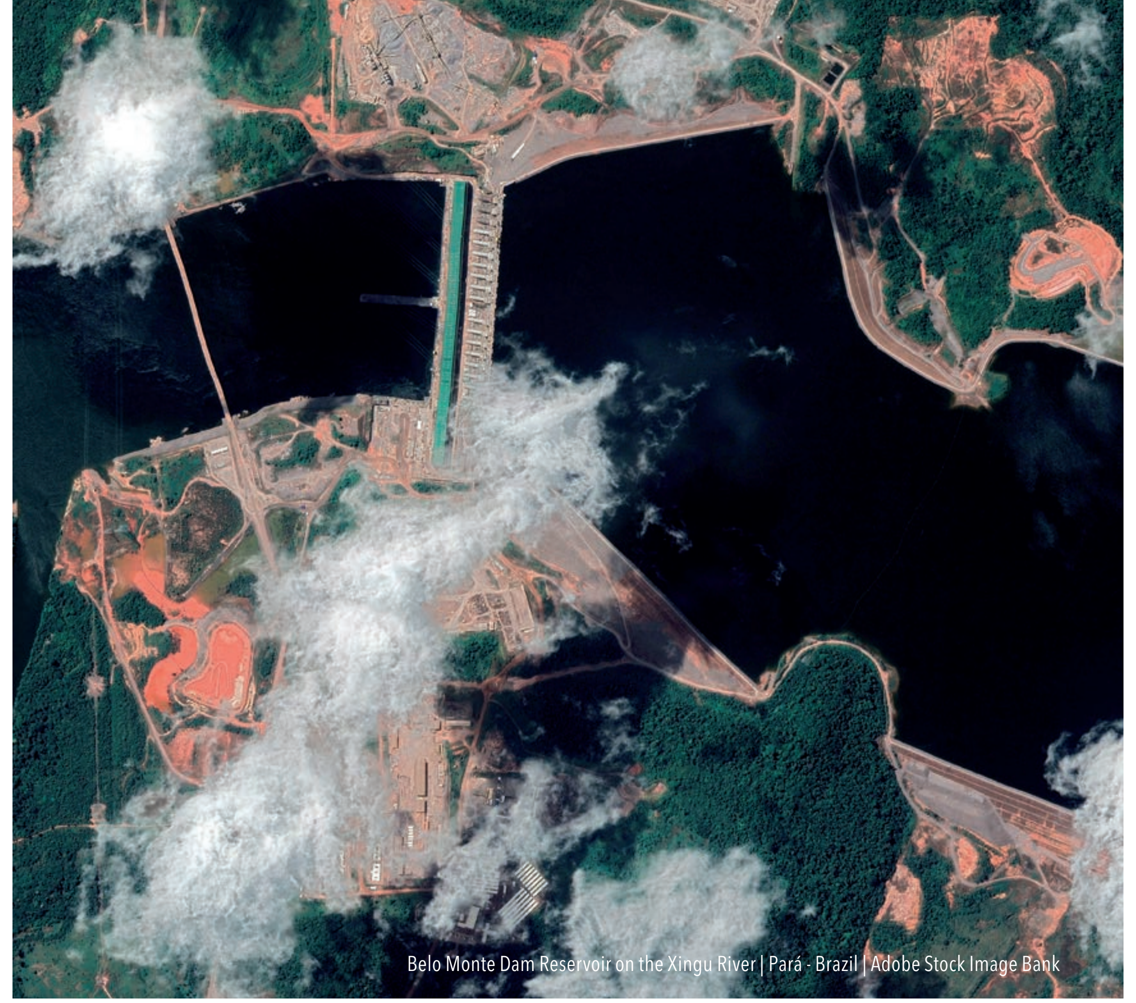
Legend

HPH
- Planned
- In operation
- Under construction

SHP
- Planned
- In operation
- Under construction

Type	HPH	SHP
Operation	49	118
Construction	59	15
Planned	88	127

Source: RAISG (2020) data processed by Cobrape.
See table of sources on page 45, item 7.



Belo Monte Dam Reservoir on the Xingu River | Pará - Brazil | Adobe Stock Image Bank

3.6. OIL EXPLORATION

According to the study "Amazonia under pressure" (own translation - RAISG, 2020), one of the activities impacting on the water resources of the Amazon Basin is oil activity, which represents 9.4% of the surface area, concentrated in the Andean Amazon (Bolivia, Colombia, Peru and Ecuador). The environmental pollution resulting from oil activity occurs mainly in the extraction areas and during the transportation of crude oil to the large refineries. Since waterways are the main means of transport, there is high risk of oil spillage into waterways.

Despite the extensive area of this activity in the basin, as shown in Figure 17, few areas of oil exploration can be observed, since most of the fields are in the exploration and potential categories. The largest exploited areas are located southwest of Putumayo (Colombia and Ecuador) and around Santa Cruz de la Sierra (Bolivia).

Contamination of water bodies by oil, and its derivatives, affects both surface and underground waters, with long-term damage. Among the recent accidents caused by oil extraction in the Amazon Basin, the following stand out:

• In 2010, in Peru, a spill of approximately 500 barrels at the height of the San José de Saramuro Native Community, caused by the exploitation of oil and derivatives, affected the Corrientes, Pastaza, Tigre and Marañon basins;

• In 2016, a large-scale spill caused the Peruvian government to declare state of emergency in 16 communities in the Loreto region. The spill of 3,000 barrels of oil into the Marañon river basin, caused by the rupture of the country's main oil pipeline, polluted stretches of the Chiriaco and Morona rivers;

• In April 2020, a spill occurred in the Napo and Coca rivers in Ecuador. The spill was about 15,000 barrels, affected more than 2,000 Indigenous families and compromised access to drinking water for at least 120,000 people.

Despite the accidents involving the oil industry, no water quality monitoring points were identified by government agencies in these regions, whether already impacted or not. This data gap poses a risk by not allowing for the monitoring and understanding of how the activity impacts water resources.

Oil is a source of hydrocarbons in water that, depending on the concentration, can be harmful to health. Furthermore, oil mousse causes damage to aquatic biota, intoxicating organisms and preventing their vital functions. There is also the risk of poisoning birds and other animals that come into contact with these substances.

In the event of a spill in coastal environments or riverbanks, the residual oil material, after evaporation and solubilisation of the light fractions, forms a kind of unstable gelatinous emulsion known as "mousse".

The oil lots with exploration permits are mostly concentrated in the Marañon/Solimões sub-basin, mainly in Ecuador, but also present in Peru, Colombia, and Brazil. These lots are a controversial issue in territorial disputes with traditional communities, mainly in Ecuador and Peru, which have gained greater proportion with the cases of spills of products derived from this type of extractivism, such as the one that affected the Corrientes, Pastaza, Tigre and Marañon basins in 2010 (BUENO and RIQUELME, 2016). The strong presence of this type of industry in the region affects water quantity and quality, limiting access for people and generating disputes over water.

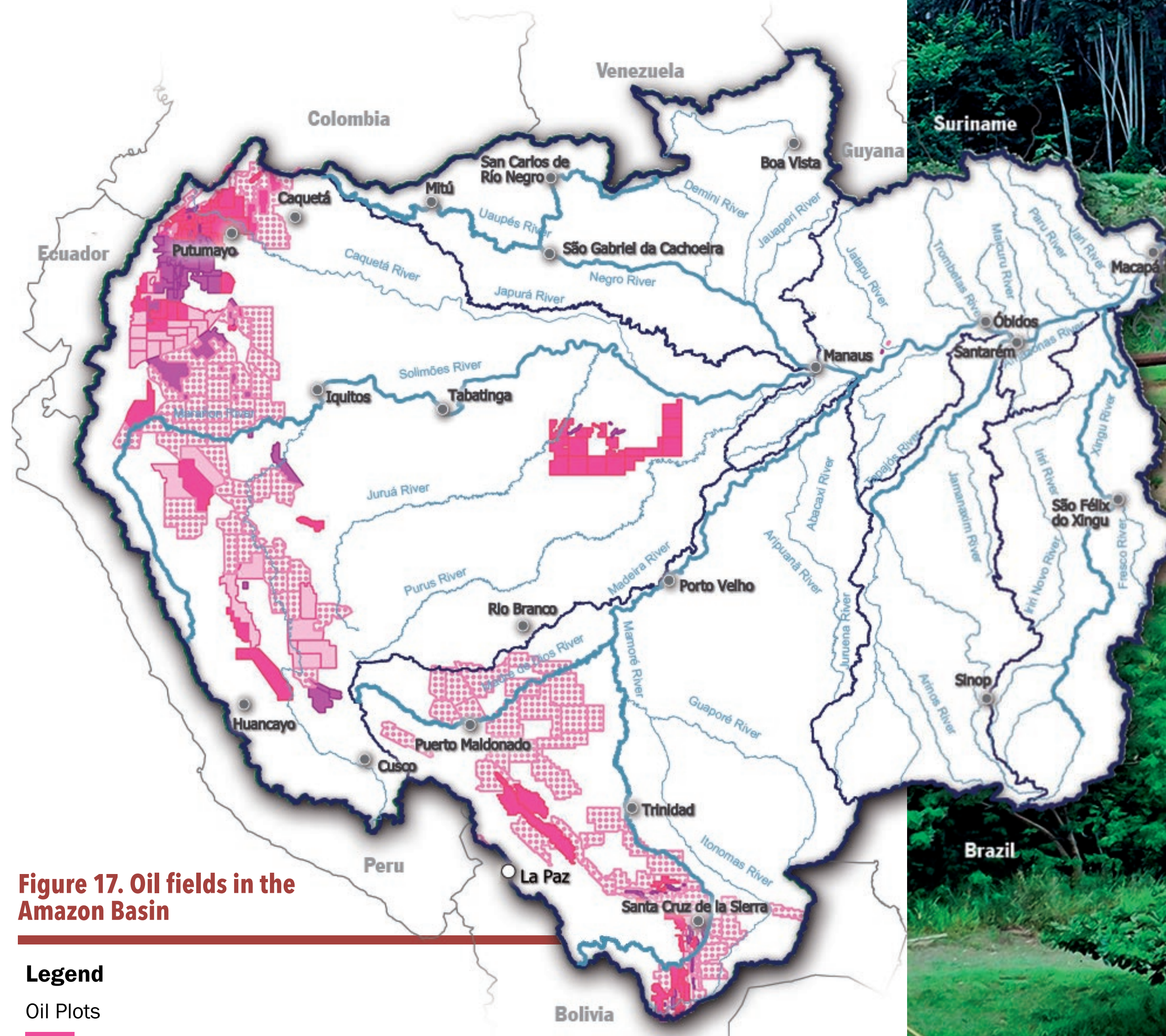


Figure 17. Oil fields in the Amazon Basin

Legend

Oil Plots
- In exploitation
- In exploitation
- Potential
- Request

Source: RAISG (2020) data processed by Cobrape.
See table of sources on page 45, item 8.

3.7. DOMESTIC SEWAGE AND SOLID WASTE

The basic sanitation sector, more specifically domestic sewage and urban solid waste, is one of the pressures identified.

Despite an abundant water supply, the coverage of public drinking water and sanitation services in the Amazon region is alarming. It is estimated that about 61% of the people living in the Andean-Amazon rain forest lack potable water services and at least 70% do not have sewerage services. Tons of liquid and solid waste are dumped directly into rivers.

Domestic sewage is rich in organic matter which, when discharged into water bodies in large quantities, can reduce the dissolved oxygen, causing fish mortality and making the water unsuitable for consumption. Furthermore, they contain substances such as detergents, nutrients, and pharmaceutical products, which alter the natural characteristics of water bodies and can be harmful to biota and human health.

With regard to solid waste, pollution can be associated with the carriage and direct deposition of this material in rivers, banks and streams. Water quality is affected in several ways, such as through the dispersion of plastics, metals and toxic materials from lamps and batteries. In addition, the improper disposal of waste causes the absorption of leachate, resulting from decomposition, by water bodies. This material has a high organic load and may contain heavy metals and other toxic materials.

Pollution from domestic sewage or solid waste is a problem directly related to rapid urbanization and the lack of adequate infrastructure for the treatment and disposal of these materials. This case is quite common in the municipalities of the ARB. Despite this, there is little official data on sanitation infrastructure and on how these sources of pollution impact the quality of water bodies, with only press and NGO reports and specific studies in scientific papers on the situation. In Brazil, the "Sewage Atlas" by ANA stands out, presenting the current scenario, analyzing data, and proposing actions and strategies for investment in sewage for all 5,570 Brazilian municipalities, with a horizon of 2035.

In studies of more specific scales, the NGO Mamirauá Institute, which operates in the Middle Solimões region, reports large amounts of waste in the forest, where the presence of 600 grams of waste per hectare was found in a study area of 2.5 hectares (IDSM, 2019). In the same study, the Forest Ecology Research Group observed waste from other countries, which proves that materials end up being transported by water bodies. Other studies report the presence of microplastics in fish and streams in the region, as the research conducted by Ribeiro-Brasil *et al.* (2020) who found nanoplastic and microplastic in the gills of fish analyzed in Brazilian territory.

In light of this broad problem, the ACTO, together with the 8 countries, has been working on the issue for the first time at a regional level. To this end, information is being collected to identify the gap in sociodemographic inequality, as well as in water, sanitation, and solid waste, with the goal of improving the Comprehensive Management of Water Resources with an emphasis on quality, through strategic planning regarding the provision of services in these three sectors in the Amazon region.

Iquito - Peru | Adobe Stock Image Bank

3.8. WATERWAYS

The use of rivers as transport routes has always been a determining factor in the settlement and presence of the state in the region.

When well maintained and managed, waterways have several positive social, economic, and environmental impacts for the region. According to Oliveira (2016), the main advantages are:

- Greater vocational integration - they facilitate regional integration, with great importance in the cargo and passenger transport;
- Increased use of inland navigation - possibility of greater reach in regions of difficult access by other means of transport;
- Greater reach to isolated regions or new river routes - provides isolated communities with social benefits, such as access to health and education, and economic benefits, such as the flow of local production to more developed centres;
- Greater use of water resources - possibility of regional development, with the expansion of arable areas, flood control, harmonious use of water with other sectors, among others;
- Higher opportunity cost - in comparison with other modalities, waterway transport has greater energy efficiency, longer useful life of equipment and infrastructure, greater cargo concentration capacity, lower operational and freight costs, among others;
- Greater regional development - possibility of forming new urban-industrial centres, as well as intensifying and facilitating the flow of commerce on a national, regional and international level.

Although a network of waterways has not yet been formally established within the basin (Figure 18), with the exception of the Madeira waterway linking Porto Velho to Itacoatiara, the member countries of ACTO have created a working group to draft and approve a Regulation for Commercial Navigation on the Amazon Rivers. This is the first step towards the future network of waterways, which will have its most important axis in the Amazon/ Solimões River channel, that is, the connection between Belém do Pará and Pucallpa, in Peru, with the river ports of Manaus, Tabatinga, Letícia (CO) and Iquitos (PE), as well as Itacoatiara, as the main intermediate points.

In the context of comprehensive and integrated water resources management, which is one of the main goals of the ACT, the regulation should certainly address the impacts of navigation, with a view to its environmentally sustainable operation.

There are several types of impacts to be assessed for mitigation purposes, being the first pollution from vessel traffic in the form of gases and oils from the engines and various waste products, in addition to the risk of spillage of fuel and other types of toxic cargo.

On the other hand, there is evidence that the densification of navigation may increase the speed of the water body, increasing the risk of flooding and altering the hydrodynamic characteristics that influence its physical and chemical processes; or even erosion of the banks and sedimentation of the rivers, which increases the amounts of suspended solids and may cause the reduction of aquatic organisms.

Finally, there is the impact on biodiversity, as it affects the migratory and reproduction processes of fish and other aquatic species (BUCHER and HUSZAR, 1995).

The main channel of the Amazon Basin is also affected by international commercial traffic, with the flow of large vessels in the stretch from Itacoatiara to the Atlantic, which are mainly responsible for shipping bulk production. In addition, there is the risk of accidents with the transport of toxic products and the disposal of ballast water, which can bring exotic species to the region, compromising the quality of water bodies and their ecosystem balance.

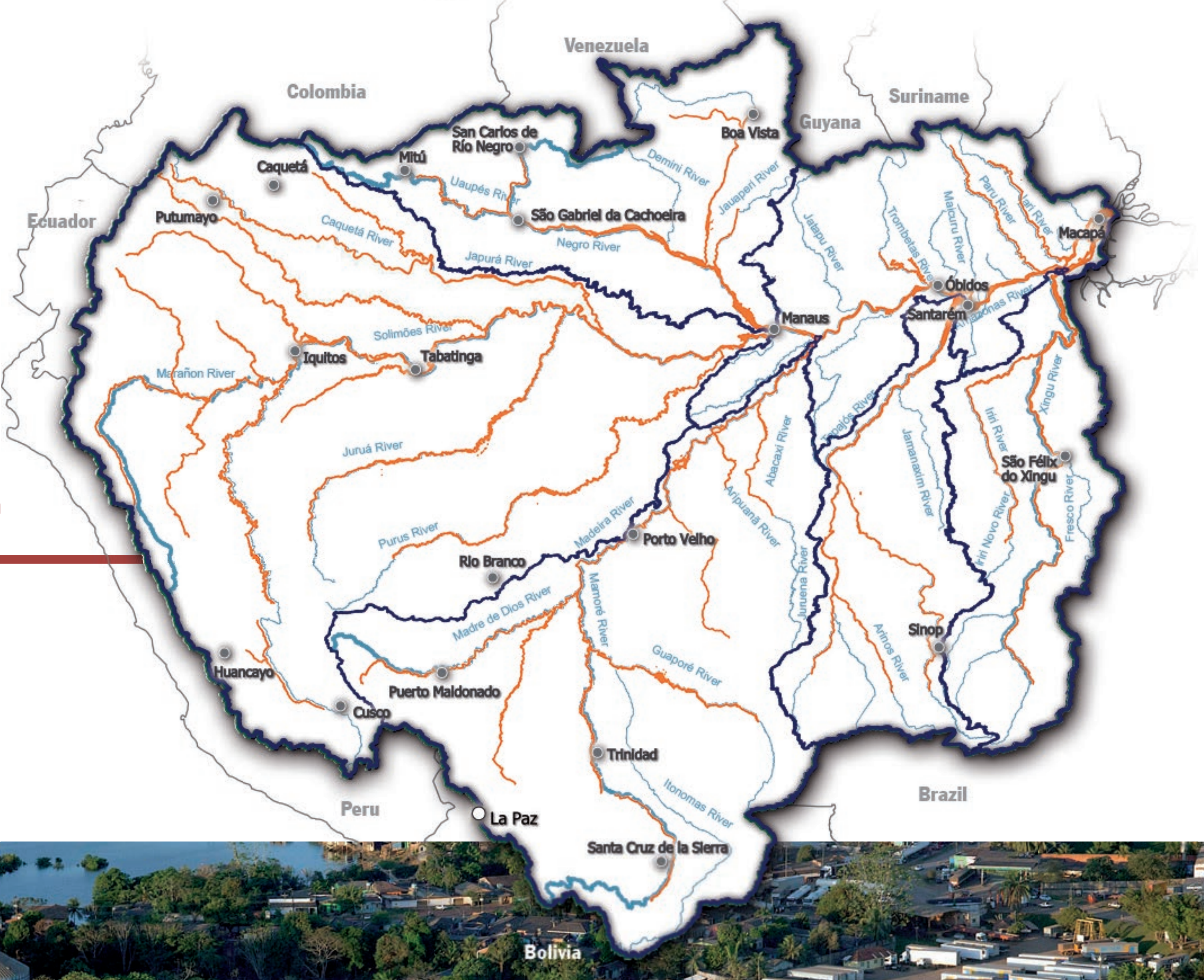


Figure 18. Waterways in the Amazon Basin

Legend

Waterways

Source: Adapted from OTCA (2021).

Cargo transport on the Madeira River waterway | Porto Velho - Brazil | Adobe Stock Image Bank

3.9. CLIMATE CHANGE

Climate change can also be considered a pressure on the quality of Amazonian waters, although it is not yet possible to relate it directly to existing monitoring data.

The pressures presented, more specifically burning, deforestation and livestock are some of the activities responsible for the increase in greenhouse gas emissions, which is directly related to climate change.

The Amazon biome is characterized by high rainfall rates. However, the region has had repeated periods of drought that are related to climate change - significant droughts were recorded in 2005 and 2010. During these periods, drastic reductions in oxygen levels in streams and lakes are observed as a result of the low renewal of water.

This "still water", with low oxygenation, is the main cause of death of a large number of fish and other aquatic organisms. On the other hand, the putrefaction of these animals consumes more oxygen, which aggravates the situation even more. In this scenario, riparian populations are hindered in their economic and daily activities, in addition to becoming more vulnerable and compromising their livelihoods (ANA, 2012).

The Intergovernmental Panel on Climate Change (IPCC), through the AR6 Report released in 2021, addresses more accurately the simulations of climate change. With the reduction of uncertainties related to the simulations, the reduction of carbon emissions discussed earlier among countries needs a more pragmatic attention.

The report is based on five emissions simulations, a set called CMIP6 (Coupled Model Intercomparison Project Phase 6). There are two low emission scenarios, one medium emission scenario and two high emission scenarios. The resulting estimates for Amazonia and the basin as a whole are alarming and demonstrate that the possible scenarios can no longer be compared to natural climatic cycles.

Also, according to the eport, the Amazon Basin should experience greater aridity, considering the decrease in global relative humidity seen since 2000 and projecting increases in evaporation rates, which consequently generates less soil moisture.

Another alarming prediction refers to temperature, since the report states that the number of days per year with temperatures exceeding 35 °C may increase by more than 150 days per year by the end of the century.

For South America as a whole, average rainfall is projected to change in a dipole pattern increasing in the northwest and southeast and decreasing in the northeast and southwest. An increase in wind speed is also predicted, which could make the Amazon region an area of wind potential.

Although the report pointed out that part of the global vegetation cover had a 7% increase between the years 1982-2016, in the Amazon an "area of darkening" was noted, that is, an area that, contrary to the global trend, has experienced decreasing green mass.

The increase in temperature intensifies evaporation, raises water temperatures, compromises aquatic life, and reduces oxygenation, which alters the physical-chemical balance of hydric bodies, besides potentially causing the death of aquatic organisms. This low oxygenation is more intense during the recurring drought periods mentioned above.

The trend towards loss of vegetation cover reinforces the scenario of changes in the natural balance of water bodies, underscored by the fact that the forest is fundamental to maintaining the floodable areas that are so characteristic of the basin.

Changes in temperature and precipitation in the Amazon Basin directly affect the so- called "flying rivers". These rivers are characterized by the large atmospheric mass generated by evapotranspiration from the dense Amazon forest, and are responsible for the macro water cycle, which is essential for maintaining the correct rainfall regime for the entire portion east of the Andes in Latin America, and therefore affecting the other hydrographic basins and neighboring biomes.

Drought in Amazonia | Adobe Stock Image Bank

4. SURFACE WATER QUALITY STATUS

Water quality indices

Water quality indices represent the composition of an indicator from monitoring data of different parameters, with the aim of facilitating data interpretation. Three of the eight ACTO Member Countries presented information on the use of water quality indices: Brazil, Colombia, and Peru. Each has its own methodology for calculating the indicator and its application in terms of water quality assessment.

Thus, in this first *Report on the status of water quality in the Amazon Basin*, no single index was defined for the evaluation of water quality, given the different methodologies and parameters monitored by the countries. The calculation methodology and the indexes presented by the three countries are described in the *Background on the water quality situation in the Amazon Basin* countries and in the *Diagnosis and Baseline on the Quality of Surface Waters in the Amazon Basin* of this study.

In order to characterize the quality of the water as regards organic pollution and given t h e low availability of data relating to the monitoring of indicators of this type of pollution, a Potential Organic Pollution Indicator (POPI) was drawn up, shown below.

It should be noted that the results of the water quality assessment were obtained based on the data from the monitoring carried out by the Member Countries and made available for this study, which excludes Ecuador, Guyana, Venezuela and Suriname.

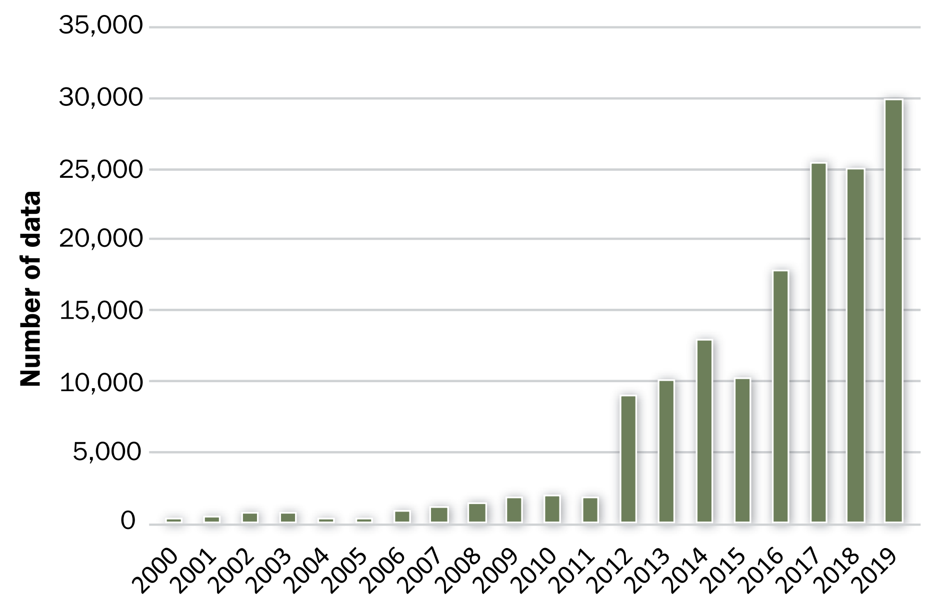
Amazon River | Brazil | Adobe Stock Image Bank

The methodology adopted to assess the "State" takes into account the legal water quality standards of the ACTO Member Countries. Thus, the legal limits of each country associated with the use of water for public supply and the protection and conservation of aquatic environments were considered. In case there were different limits, they were divided into more and less restrictive ones.

Water quality monitoring data

The water quality assessment for the report was based on monitoring data received from Bolivia, Brazil, Colombia, and Peru. Figure 19 presents a summary of the number of these water quality monitoring data, which refer to the period from 2000 to 2019[5]. It is possible to observe a significant increase in the last three years, which is mainly related to monitoring in Bolivia, which only began in this Basin in 2016.

Figure 19. Water quality monitoring data available by year

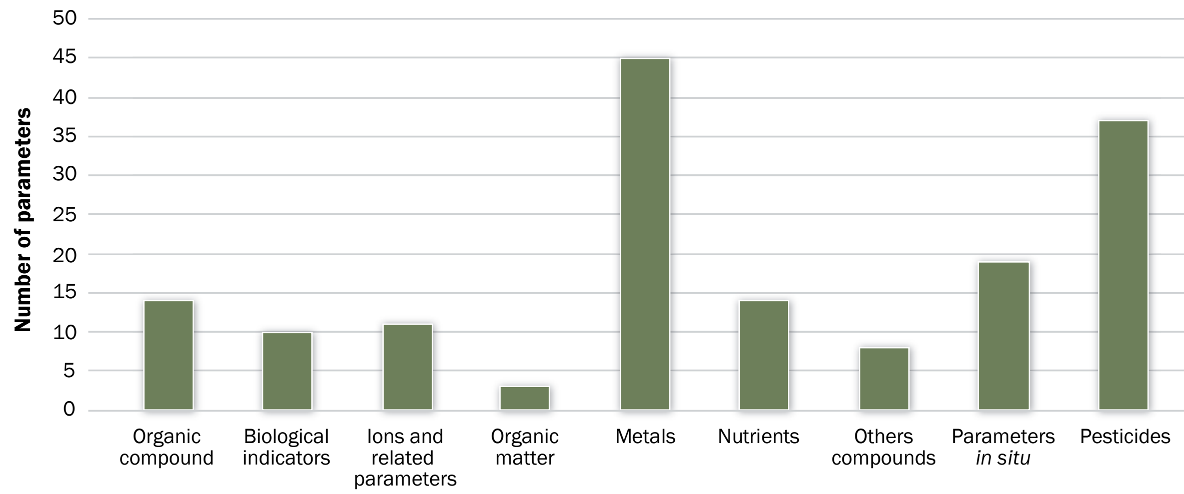


Source: Cobrape (2021), adapted from data received from Member Countries.

The data received totals the monitoring of 161 different parameters distributed into categories as shown in Figure 20, with variation of these parameters by monitoring point, even within the same country. Although the categories related to metals and pesticides present more parameters, they are monitored mostly in Peru, the country that presented the most data.

The most monitored parameters in terms of spatial distribution are those in the category called *in situ*, which represent those determined in the field, among which stand out pH – the parameter most monitored by all countries – dissolved oxygen, temperature, turbidity, and solids.

Figure 20. Parameters monitored per category



Source: Cobrape (2021), adapted from data received from Member Countries.

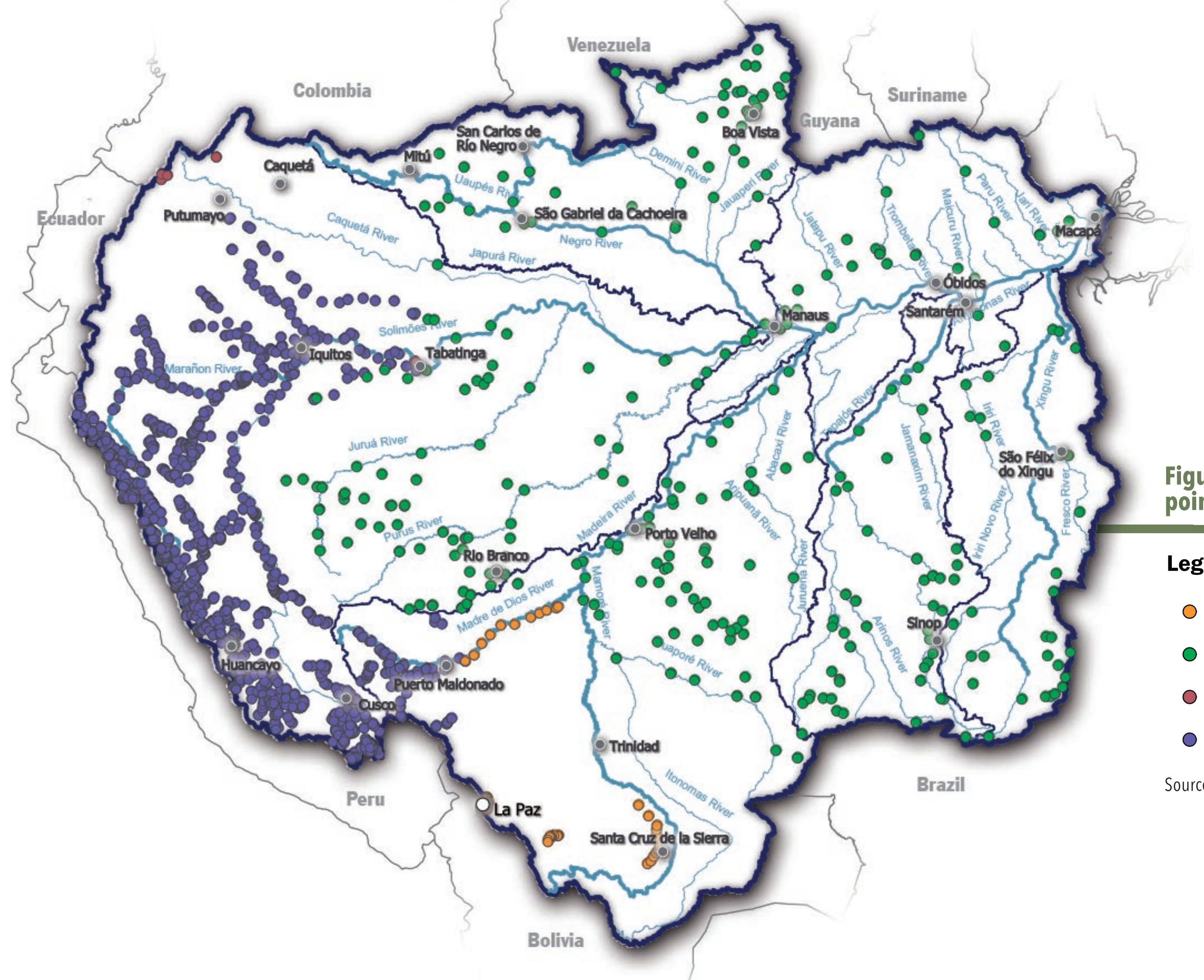


Figure 21. Existing monitoring points in 2021

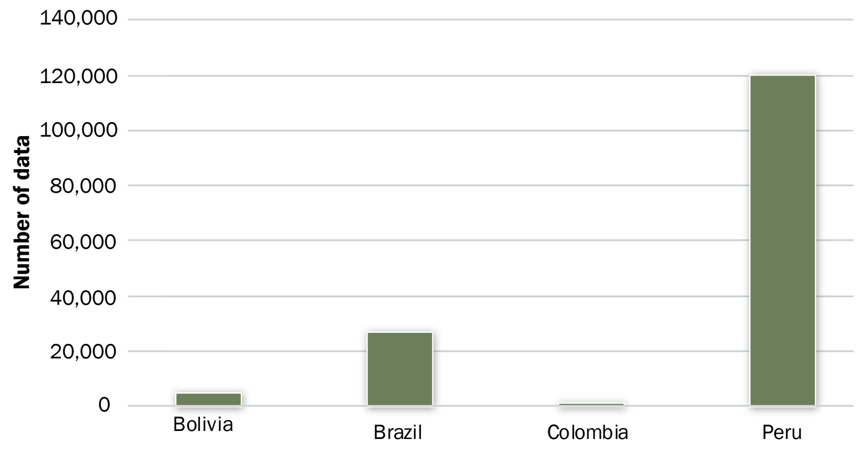
Legend

- Bolivia Stations
- Brazil Stations
- Colombia Stations
- Peru Stations

Source: Data received from Member Countries.

[5] It is noteworthy that Ecuador did not provide monitoring data, Guyana and Venezuela do not monitor the Amazon Basin in their territory and Suriname has no water bodies in the basin.

Figure 22. Available water quality monitoring data by country



Source: Cobrape (2021), adapted from data received from Member Countries.

All data received (Figure 22) came from the 1,938 monitoring points presented in Figure 21, with a breakdown by country.

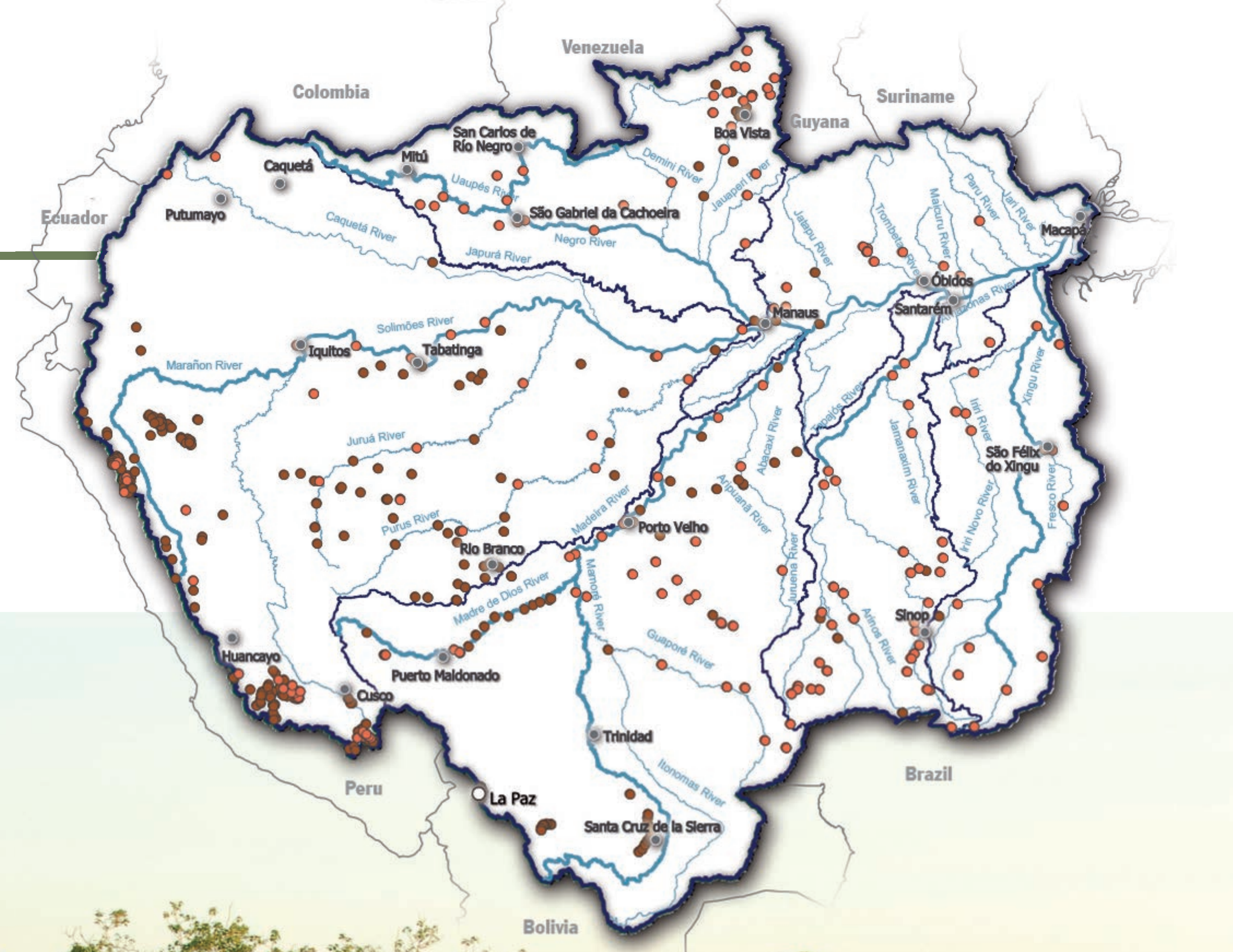
Subsequently, the data was consolidated to exclude those points with erroneous locations and without monitoring of the selected parameters for the period of analysis, resulting in 705 stations. As shown in Figure 23, they were separated among those that presented data only for the year 2019 and those that had a minimum period of seven years.

Figure 23. Stations with data in 2019 and in the last seven years for the analysis of the water quality situation in the ARB

Legend

- Stations with data in 2019
- Stations with at least seven years of data

Source: Data received from Member Countries.



Other monitoring data

Due to the large extension of the Amazon territory and the high costs of conventional monitoring, technological alternatives have been sought to supply the need for hydrological monitoring in its temporal and spatial scale.

ANA/Brazil, in partnership with the French research agency Institut de Recherche pour le DéVeloppement (IRD), has been developing since 2009, through an agreement with the Brazilian Cooperation Agency, the Technical Cooperation Project Hydrological Spatial Monitoring of Large Basins (MEG-HIBA Project). The project consists in obtaining hydrological data collected from satellite sensors, called "virtual stations". Through these radars, river and reservoir level estimates and information for assessing water quality were developed. These results are made available on the Hidrosat portal[6]. The Hidrosat data for the Amazon Basin includes information on suspended sediment concentration for 15 stations between 2000 and 2021.

A similar project is developed through the SO-Hybam (Current Hydro-Geodynamics of the Amazon Basin)[7] Observation Service, in operation since 2003 in eight countries, with scientific and technical partners from Brazil, France, Venezuela, Colombia, Ecuador, Peru, Bolivia and Congo. SO-Hybam provides watercycle data for the Amazon Basin region through online databases and documents that share all the content produced by the observatory since its creation. The monitoring has 13 stations located in the ARB's area of interest and the parameters analyzed are organized into the following categories: physical (temperature, electrical conductivity), chemical (totaling 46 different parameters analyzed, including pH).

[6] hidrosat.ana.gov.br.
[7] hybam.obs-mip.fr.

Water quality analysis

From the consolidated data, the analysis of water quality in the Amazon Basin was based on three aspects:

- Analysis of the current situation: represented by the average of the data monitored per station in 2019, considering the hydrogeochemical characteristics defined by Rios-Villamizar *et al.* (2020) and the legal limits of each country;
- Trend analysis: it was verified whether in the seven-year monitoring period there was an increase, reduction or stability in the monitored values, which may indicate that the water quality condition worsened, improved or remained constant in the period;
- Potential Organic Pollution Indicator (POPI): it was defined based on the estimate of organic matter from urban domestic effluents. An estimate was made of the concentrations resulting from the dilution by the Amazon rivers of the BOD load generated by the urban population. These concentrations parameters were compared with the limits defined in the appropriate countries' laws for water intended for public supply and protection and conservation of aquatic environments, following the definition of good quality water of the UN Sustainable Development Goals. It should be noted that the proposed POPI is specific to the Amazon Basin, considering the current legislation in the member countries of ACTO, and should not be applied to other basins or in situations where legislation is changed. This compatibility resulted in the water quality categories presented in Table 2:

Table 2. Categories of the Potential Organic Pollution Indicator (POPI)

Category	POPI	Interpretation
Very good	≤ 1	The river flow is sufficient to dilute the incoming load to a BOD concentration of up to 5 mg/L
Good	1 < POPI ≤ 2	The river would need a flow rate up to 2 times greater than the current one to dilute the incoming load and stay with a BOD concentration of up to 5 mg/L
Regular	2 < POPI ≤ 4	The river would need a flow rate between 2 and 4 times greater than the current one in order to dilute the load received and have a BOD concentration of up to 5 mg/L
Bad	4 <POPI ≤ 8	The river would need a flow rate between 4 and 8 times greater than the current one in order to dilute the load received and have a BOD concentration of up to 5 mg/L
Very Bad	> 8	The river would need a flow rate greater than 8 times the current one to dilute the incoming load and stay with a BOD concentration of up to 5 mg/L

Ten water quality parameters were analyzed: electrical conductivity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), phosphorus, nitrate, dissolved oxygen (DO), pH, total dissolved solids, and turbidity. Among them, electrical conductivity and pH stand out, with more monitoring data in the basin and directly related to the hydrogeochemical characteristics of Amazonian waters, and dissolved oxygen (DO), consumed in the stabilization process of organic matter.

Of the ten parameters analyzed in the preparation of the **Report on the Status of Water Quality in the Amazon Basin**, the main results of three of them (conductivity, pH, dissolved oxygen) are presented below, given the representativeness of the data and their relationship with the hydrogeochemical characteristics. Additionally, the estimated POPI for ARB and considerations about metals are presented, since mining is one of the greatest pressures identified.

4.1. ELECTRICAL CONDUCTIVITY

The evaluation of the electrical conductivity in the Amazon Basin, presented in Figure 24, indicated that in 2019 most stations presented average values compatible with the expected range of values for each type of water. The exceptions were observed for:

- Black waters (conductivity <20 µS/cm): three stations in the Marañon/Solimões sub-basin, located in floodable regions and with deforestation foci, presented conductivity higher than expected for this category of water. In the lower Amazon sub-basin, three stations presented average values below the expected for this category of water;
- Intermediate Type A waters (average conductivity of 18.9 µS/cm.): the majority of stations in rivers of this category located in the Vaupés/Siapa/Negro sub-basin presented conductivity averages higher than expected. This situation was also identified in a station in the Teles Pires River, Tapajós sub-basin, and in one in the Xingu sub-basin. In all cases, the drainage areas of these stations have focuses of deforestation and agricultural activity. In the Baixo Amazonas sub-basin, some stations showed average values below expectations, although some deforestation foci were identified. Values significantly below the expected were verified at stations located in the headwaters of the Xingu sub-basin, despite intense agricultural activity;
- Intermediate Type B waters (average conductivity of 21.9 µS/cm): this category occurs only in the Marañon/ Solimões sub-basin, in which only one station showed an average value much higher than expected, which can be associated with the deforestation that occurs in the region;
- White waters (conductivity between 30 and 140 µS/cm): values lower than 30 µS/cm were reported at two stations on the Madeira River. Values higher than 140 µS/cm were observed at one station on the Marañon River and one on the Solimões River, both located in areas subject to flooding, which may justify the higher values. These high values were also verified at ten stations in the Piraí River, in a region of intense urbanization in the city of Santa Cruz de La Sierra;
- Clear waters (conductivity between 5 and 40 µS/cm): the majority of stations located in rivers in this category presented average values compatible with the expected range of values. The exceptions occurred in two of the Madre de Dios/Madeira/Mamoré sub-basin, which showed average conductivity greater than 40 µS/cm. These stations are located in stretches close to the transition of categories, in the Mamoré and Guaporé rivers;
- No defined category: seven stations in the Marañon/Solimões sub-basin presented values above the legal limit, 1,600 µS/cm, in which legal and illegal mining was identified as the greatest pressure.

Most of the stations with sufficient data for trend analysis indicated stationary behavior. A downward trend was identified in four stations in the Marañon/ Solimões sub-basin and one in the Madre de Dios/Madeira/Mamoré sub-basin. Three of these are in whitewater rivers and one of them showed an average value below that expected already in 2019. Stations in the sub-basins Vaupés/Siapa/Negro, Madre de Dios/Madeira/Mamoré and Tapajós showed a tendency to increase conductivity, most of them within the appropriate range for their categories. Nunes (2002), in a study carried out in the Ji-Paraná River basin, located in the Madre de Dios/Madeira/Mamoré sub-basin, also observed an increase in conductivity and associated this alteration with deforestation.


Negro River | Manaus - Brazil | ACTO Image Bank

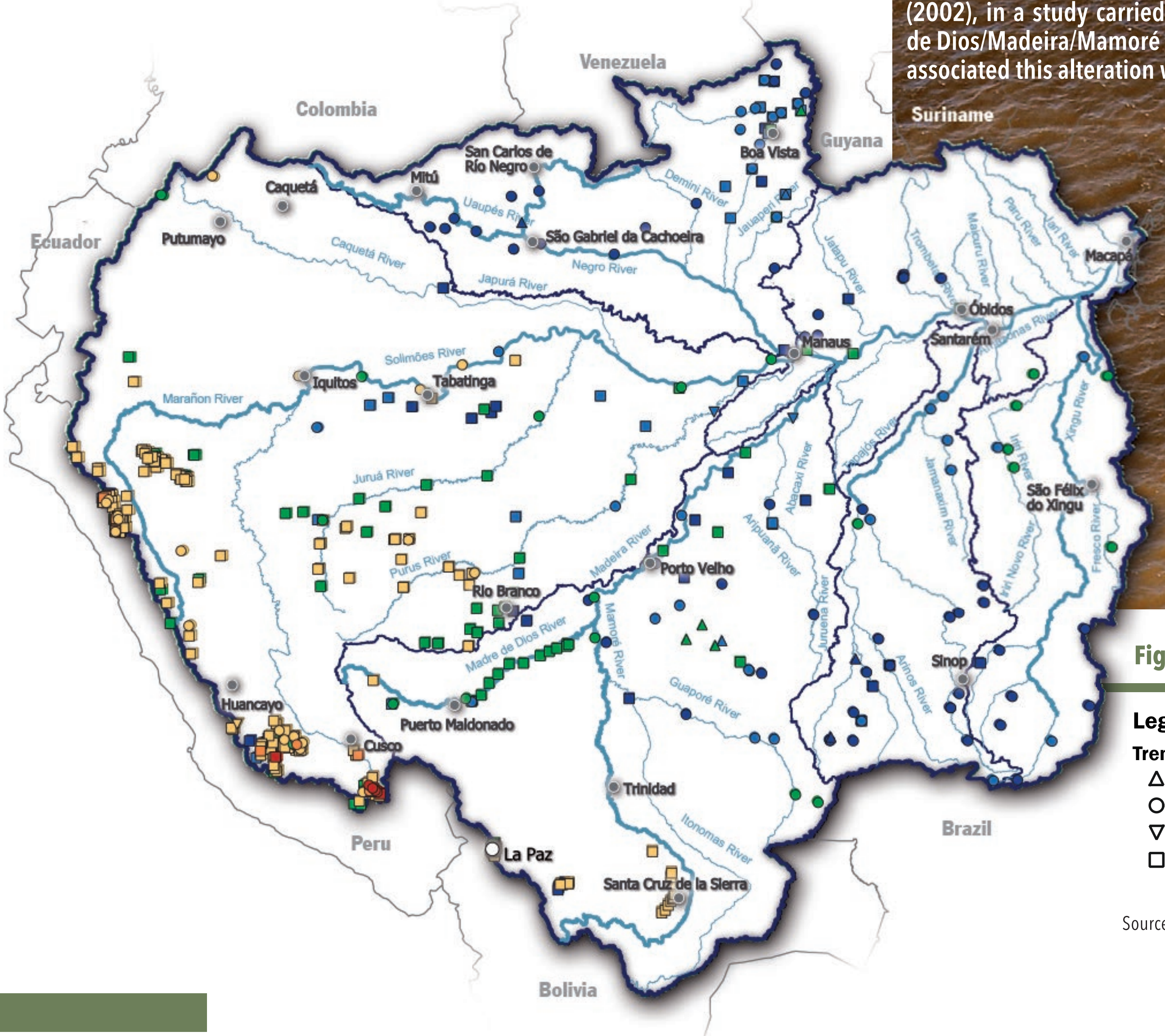


Figure 24. Electrical conductivity in the Amazon Basin

Source: Cobrape (2022).

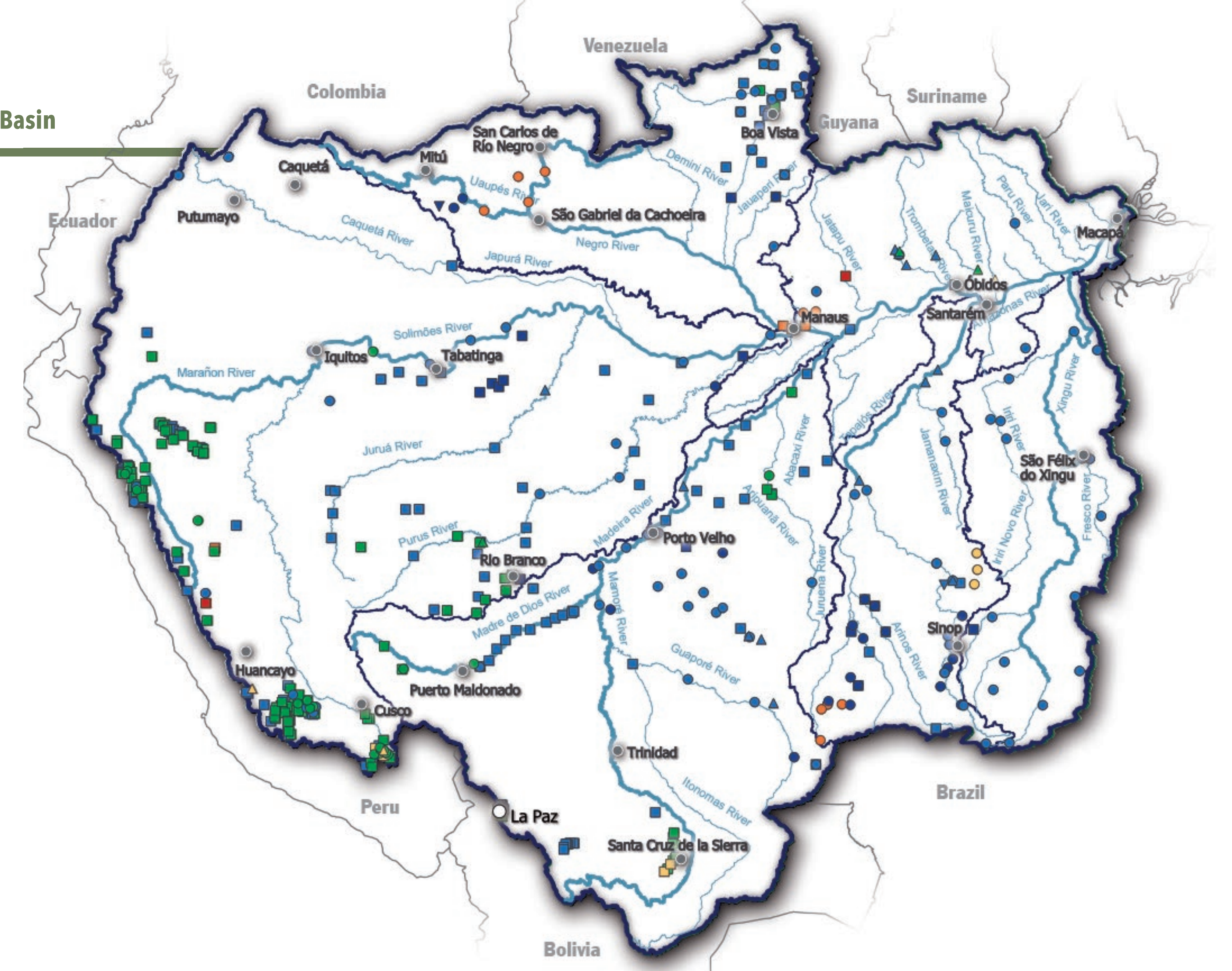
4.2. pH

The most basic pH averages in the ARB are concentrated in the Marañon/Solimões sub-basin, while several of the other sub-basins presented most averages close to neutral pH, with some specific points that are more acidic and even more basic than the upper limit of the legal range (5 to 9). In general, the averages found are consistent with what is foreseen in the legislation of all the countries and in accordance with what is expected for each type of water (Figure 25), with the following exceptions:

- Black waters (pH between 4 and 5): only two stations in the Marañon/Solimões sub-basin presented a more neutral pH than that expected for black waters. They are located on the Javari and Tefé Rivers, near small population centres;
- Intermediate Type A waters (pH average of 5.9): The majority of stations in rivers of this type in the Vaupés/Siapa/Negro sub-basin presented a more basic or more acidic pH than expected, and are in areas with intense agricultural activity. The same was noted in the sub-basins Tapajós and Xingu, with the rivers Teles Pires, Azul, Iriri and Curuá standing out. In these sub-basins there is intense agricultural activity, as well as legal and illegal mining, especially in the Xingu sub-basin;
- Intermediate Type B waters (average pH of 6.1): in the Marañon/Solimões sub-basin, more specifically in the Purus River basin, many stations presented a more basic pH than expected. They are in regions of intense deforestation and agriculture;
- White waters (pH close to 7): in the Marañon/Solimões sub-basin, two stations on the Purus River presented pH results below expectations and two showed a high average pH, one located in the Marañon River, near protected areas, and the other on the Juruá River, where there are floodable areas and oil exploration. In the Madre de Dios/Madeira/Mamoré sub-basin, stations in the Santa Cruz de La Sierra and La Paz regions showed a more basic pH, a reflection of urbanization and related activities. More basic values were also registered in the Aripuanã River, where forest areas predominate, but with the presence of agriculture and cattle ranching;
- Clear water (pH between 4.5 and 8): in the Tapajós sub-basin, three stations presented an average pH more basic than expected, one of them located in the urban area of Itaituba and the other two in areas subject to deforestation and agriculture;
- No defined category: Stations in the Colquijirca and Huallaga rivers, subject to intense mining activity, presented pH with high acidity in the Marañon/ Solimón sub-basin. One station in the Vaupés/Siapa/Negro sub-basinpresented pH below the lower legal limit (5), it is on the Uaupés River, with apparent illegal mining. This situation occurred more frequently in the Tapajós sub-basin, where seven stations presented an average pH below 5, but in this sub-basin the pH extremes observed can be more related to agricultural activity.

The trend was not identified in most of the stations that provided data, however, pH increase was identified in 20 of them, and most of them indicated a neutral pH average in 2019. However, one station in the Lower Amazon sub-basin presented average pH above 9 as well as four stations in clear water rivers of the Madre de Dios/Madeira/Mamoré sub-basin. Accordingly, it can be stated that the rivers monitored by these stations are moving away from the natural pattern. Two presented a tendency of decrease in pH, one in the Tapajós sub-basin and the other in Vaupés/Siapa/Negro. Both presented an average of neutral pH in 2019.

Figure 25. pH in the Amazon Basin



Source: Cobrape (2022).

4.3. DISSOLVED OXYGEN (DO)

Most of the analyzed stations presented good water quality conditions in terms of dissolved oxygen concentration, with averages above 5 mg/L, the legal minimum adopted by ACTO Member Countries, as shown in Figure 26.

In the Marañon/Solimões sub-basin, two stations indicated a trend of increasing concentration of DO and four of decreasing concentration, thus indicating a a more worrying situation, since they presented an average concentration below 5 mg/L in 2019. All of these stations are near urban occupations and in floodable areas, one located in the black-water Javari River and the others in the white-water Solimões River. In addition to these four, 21 more showed average DO below 5 mg/L in 2019, most of them located in floodable zones. The occurrence of mining areas near these stations is also frequent.

Mean concentrations below 5 mg/L in the Vaupés/Siapa/Negro sub-basin were observed at seven stations, five located in black water rivers, one in Intermediate type A, and one without information. Only two of them do not occur in urbanized areas, one in the Catrimani River and the other in the Paduari River, the latter in a region with deforestation areas.

Low average concentrations of DO in 2019 were found at the stations located on the Amazon River. The two with concentrations below the legal limit are downstream of Manaus, near some settlements, but in a region subject to flooding, which may contribute to the low concentrations.

In the Madre de Dios/Madeira/Mamoré sub-basin only six stations are in a critical situation of DO, three of them located on the Guaporé River, one on the Abuña River, one on the Marmelo River, a tributary of the Madeira, and one on the Rocha River in Cochabamba, although in this case the other stations nearby, on the same river, present values above 40 mg/L of DO.

Only one station in the Tapajós sub-basin, located in the Arinos River presented low concentration of DO. It is near natural protected areas but subject to flooding, which could be the cause of this value, since the other stations in this river present better results.

In the sub-basin of the Xingu River, only one station indicated a critical concentration lower than 5 mg/L. It is located in the Comandante Fontoura River, of Intermediate Type A characteristic, in a region of intense agricultural activity.

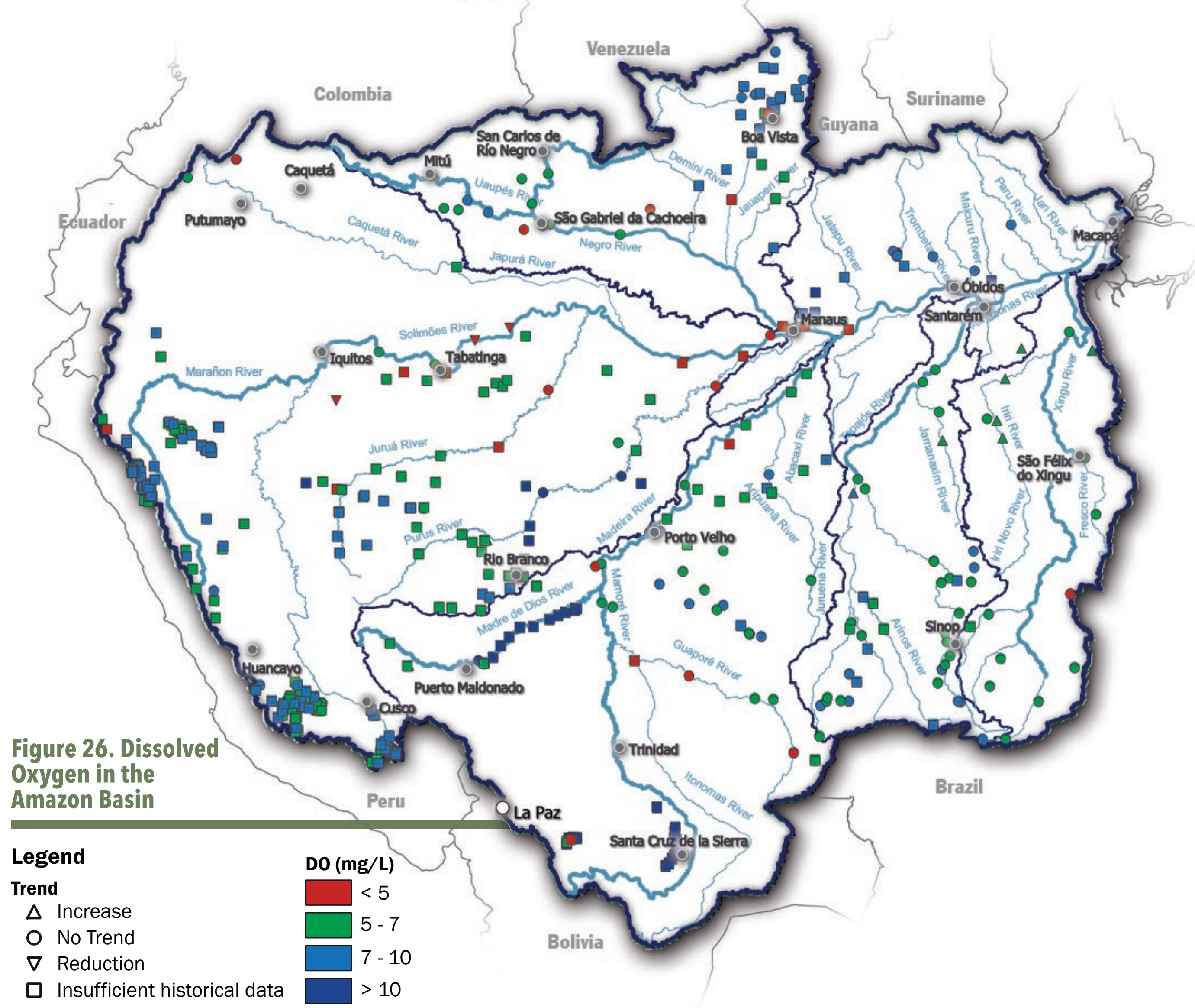


Figure 26. Dissolved Oxygen in the Amazon Basin

Source: Cobrape (2022).

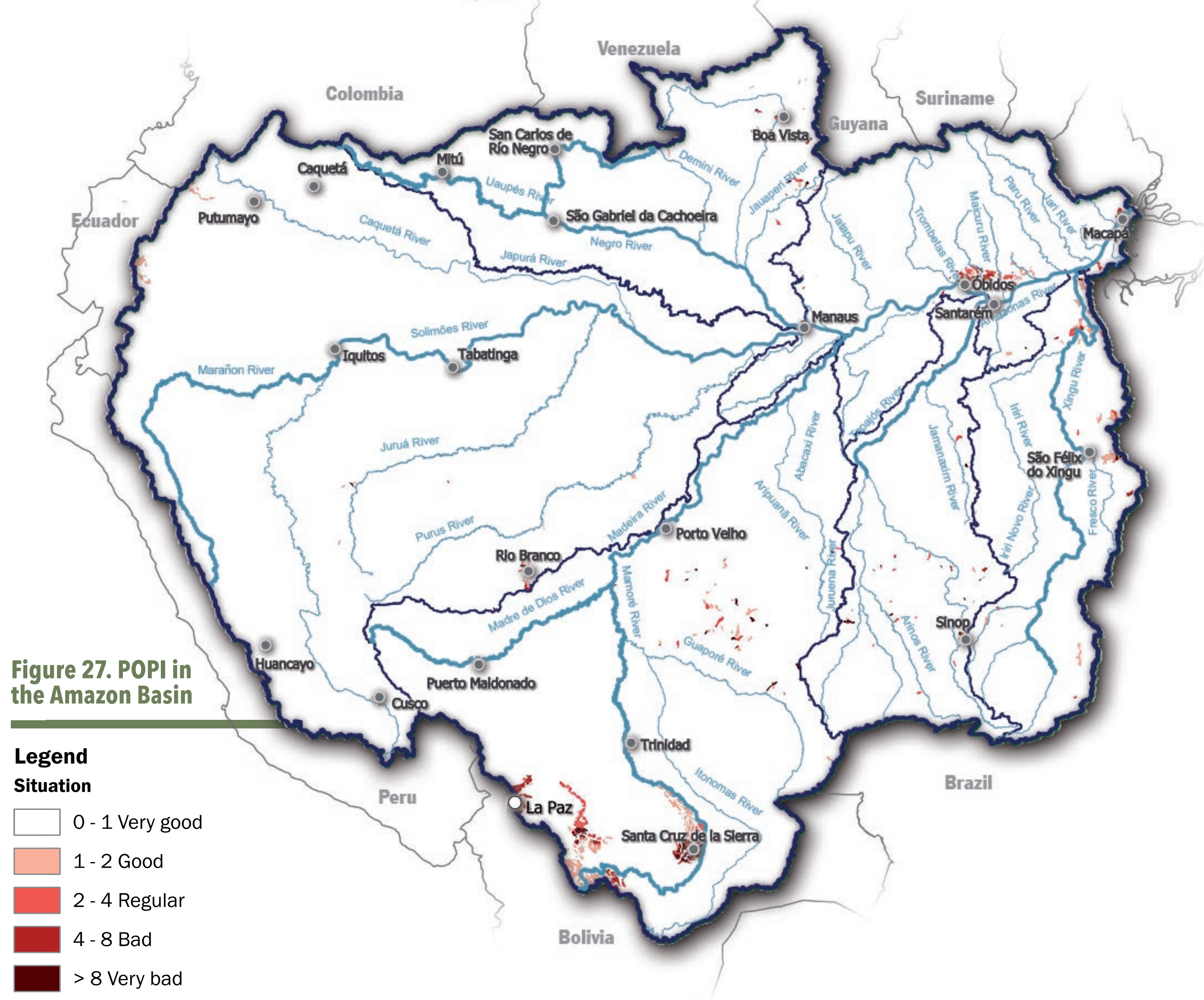


Figure 27. POPI in the Amazon Basin

Source: Cobrape (2022).

4.4. POTENTIAL ORGANIC POLLUTION INDICATOR (POPI)

According to Figure 27, most of the ARB presented an expected POI compatible with the "optimal" category, since its estimation is based on the population, which is densely populated in specific points, and resulting in the largest urban areas being highlighted as regions with poor water quality. Among them is Santa Cruz de la Sierra, the largest area with POPI with very poor water quality in the ARB, located in the Madre de Dios/ Madeira/ Mamoré sub-basin. In this sub-basin the Bolivian city of Cochabamba and the Brazilian cities Rolim de Moura, Cacoal, and Espigão d'Oeste also stand out.

In the Marañon/Solimões, Tapajós and Xingu sub-basins, small regions presented POPI of very poor quality, particularly, Rio Branco, Sinop and Altamira in Brazil.

A critical area is observed in the Baixo Amazonas sub-basin, near the Curuá river, in the municipalities of Óbidos, Curuá and Alenquer, in the state of Pará, with poor and very poor POPI. In the Vaupés/Siapa/Negro sub-basin, regions with very poor and poor POPIs are observed mainly in Boa Vista and Manaus. Regarding this municipality, it should be noted that it is the one with the largest population, but with an apparently small spot relative to criticality because the Manaus urban area is in two different sub-basins: Vaupes/Siapa/ Negro and Baixo Amazonas. Furthermore, based on the methodology employed, the location of most of Manaus' population coincides with the Negro River, whose flow is rather high, thus facilitating sewage dilution. However, part of the streams and small water bodies crossing the city are in a critical situation in terms of pollution by effluents.

To complement this study, Unicamp (2021) pointed out the presence of compounds arising from human activity and reflecting the lack of basic sanitation, such as caffeine, nicotine, hormones, painkillers and psychostimulants, which threaten the biodiversity of the Amazon River basin. This study was followed by a cal for urgent measures to reduce the release of these pollutants in water bodies.

4.5. METALS

Mining was one of the most prominent pressures in the ARB. Some stations for the analysis of water quality reported being affected by this activity, and metals are those parameters that could most directly indicate such an impact. However, only Peru monitors metals and therefore this information is available only for the rivers in the Marañon/Solimões and Madre de Dios/Madeira/Mamoré sub-basins.

Mercury (metal) and arsenic (semi-metal - metalloid) were analyzed in terms of the average and trend in 2019. It is noteworthy that these metals are among those with low solubility and therefore have low concentrations in surface waters. However low they may be, they can have adverse effects on aquatic organisms, especially fish and other upper food chain organisms, as living organisms do not metabolize these metals, so any concentration may be considered harmful (VON SPERLING, 2005). Moreover, because they are not metabolized or excreted, the bioaccumulation process occurs exposing the organism to this substance and increasing its concentration throughout its life In addition, because they are not metabolized or excreted, bioaccumulation occurs, and the concentration of a substance in an organism that has always been exposed to this substance increases over the course of its life. According to Cain *et al.* (2018), bioaccumulation can lead to concentration increase of these compounds in animals at the top of the food chain, as animals of each trophic level consume prey with higher concentrations, which is known as biomagnification.

As such, the results of the means monitored for these parameters are only indicative of the presence or absence of these substances in the water. Specific studies on the concentration of metals in living organisms are more representative of the harmful effects of mining on water quality and human health.

With regard to mercury, whose impact is most studied in the Basin, all the 2019 averages from monitoring in Peru were not higher than the most restrictive legal limit (0.0001 mg/L) and six stations located in the Marañon/Solimón sub-basin, with sufficient data for trend analysis, indicated reduced concentrations, five of which are the same ones in which arsenic concentrations were between the most restrictive and most permissible limit. The other station is located on the Marañon River, in San Juan Bautista, district of Maynas (Peru), in an area of agricultural activity, in addition to being surrounded by illegal mining. In the Madre de Dios/Madeira/Mamoré sub-basin no trend was identified.

The issue of mercury in the Amazon led to the creation of the Mercury Observatory, a platform launched by the NGO WWF in partnership with Fiocruz, Cincia and other institutions, with the aim of compiling all studies and information on mercury and mining in the Pan-Amazon region, and to provide more transparency with this information.

Through the observatory, it became apparent that although the sale of mercury is controlled in Brazil, this is not the case in all countries. It is smuggled by miners to capture gold and improperly released into the soil, water and air. Mercury becomes even more toxic when in contact with microorganisms, when it turns into methylmercury, contaminating flora and fauna and becoming harmful to human health.

The tool created by the Mercury Observatory brings together scientific literature resulting from a systematic review conducted between 1980 and 2021, compiling records of mercury in humans and in fish, illustrated in Figures 28 and 29, below.

It is noted that there is more information for humans and that several localities present very high concentrations, especially in the rivers Madeira, Tapajós and Negro. For most localities with studies conducted in fish, especially in the tributary of the main rivers, concentrations are in the range considered acceptable. The high concentrations in fish are found in the localities of Itaituba and Jardim do Ouro (Tapajós basin), Assis Brasil (Marañon/Solimões basin) and Fortaleza do Abunã and Libertad (Madre de Dios/Madeira/Mamoré basin).

Illegal mining, combined with burning and deforestation, is increasing the contamination of water, soil, animals, plants and people. The periodical El País, in 2021, provided evidence of the trail of destruction of the illegal Brazilian gold market on water resources, flora, river fauna and the health of indigenous peoples in Jacareacanga, in the southwest of the state of Pará.

Oil activity is also a source of metal contamination. Yusta-García *et al.* (2017) conducted a study involving 2,961 water samples and performed 652 chemical analyses of wastewater from government institutions and oil company reports, which were collected in four Amazon river basins (Marañon, Tigre, Corrientes, and Pastaza), and their tributaries. A significant number of water samples showed levels of cadmium, barium, chromium and lead that fail to meet Peruvian and international water standards.

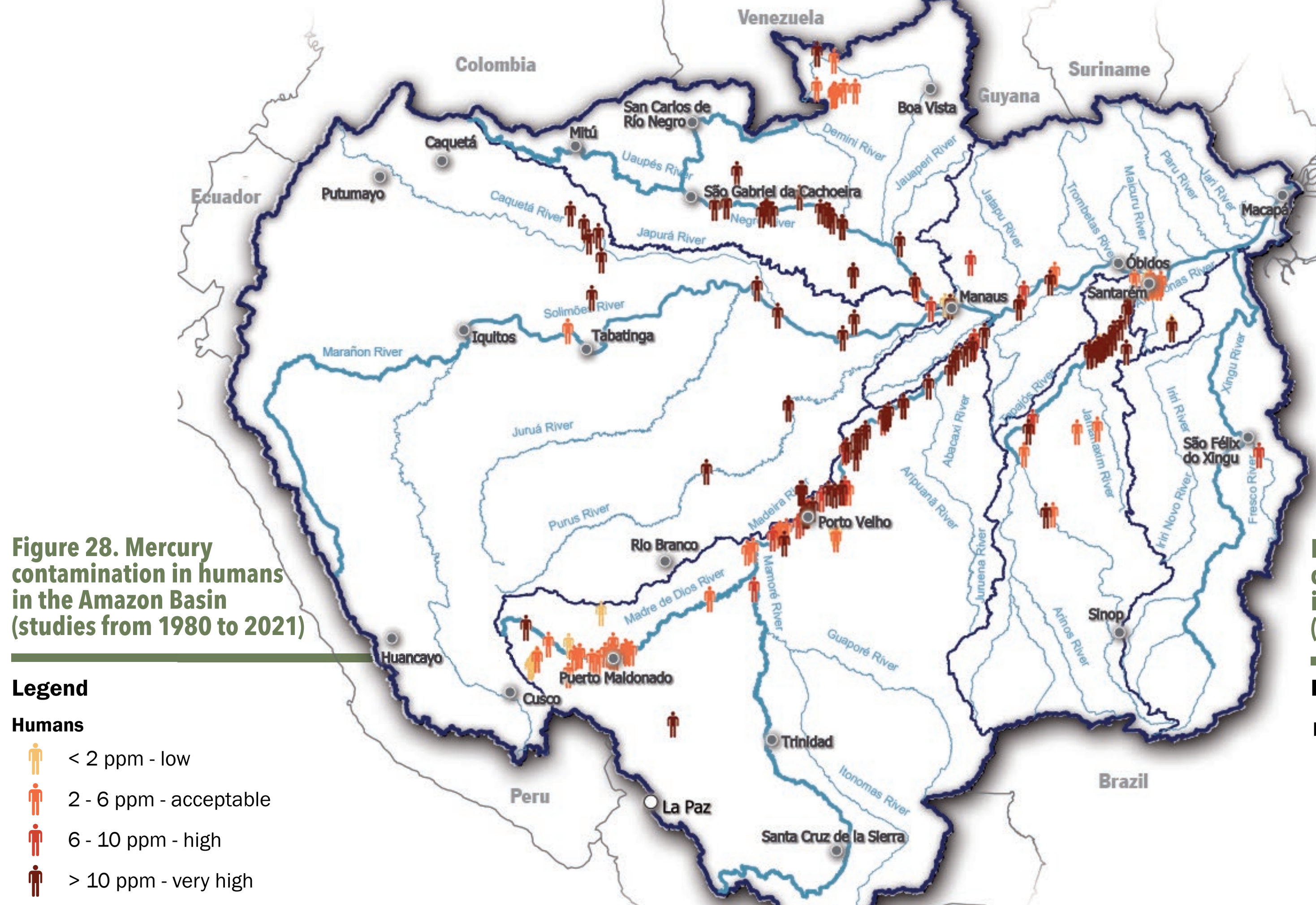


Figure 28. Mercury contamination in humans in the Amazon Basin (studies from 1980 to 2021)

Source: Observatório do Mercúrio na Amazonia (2021)

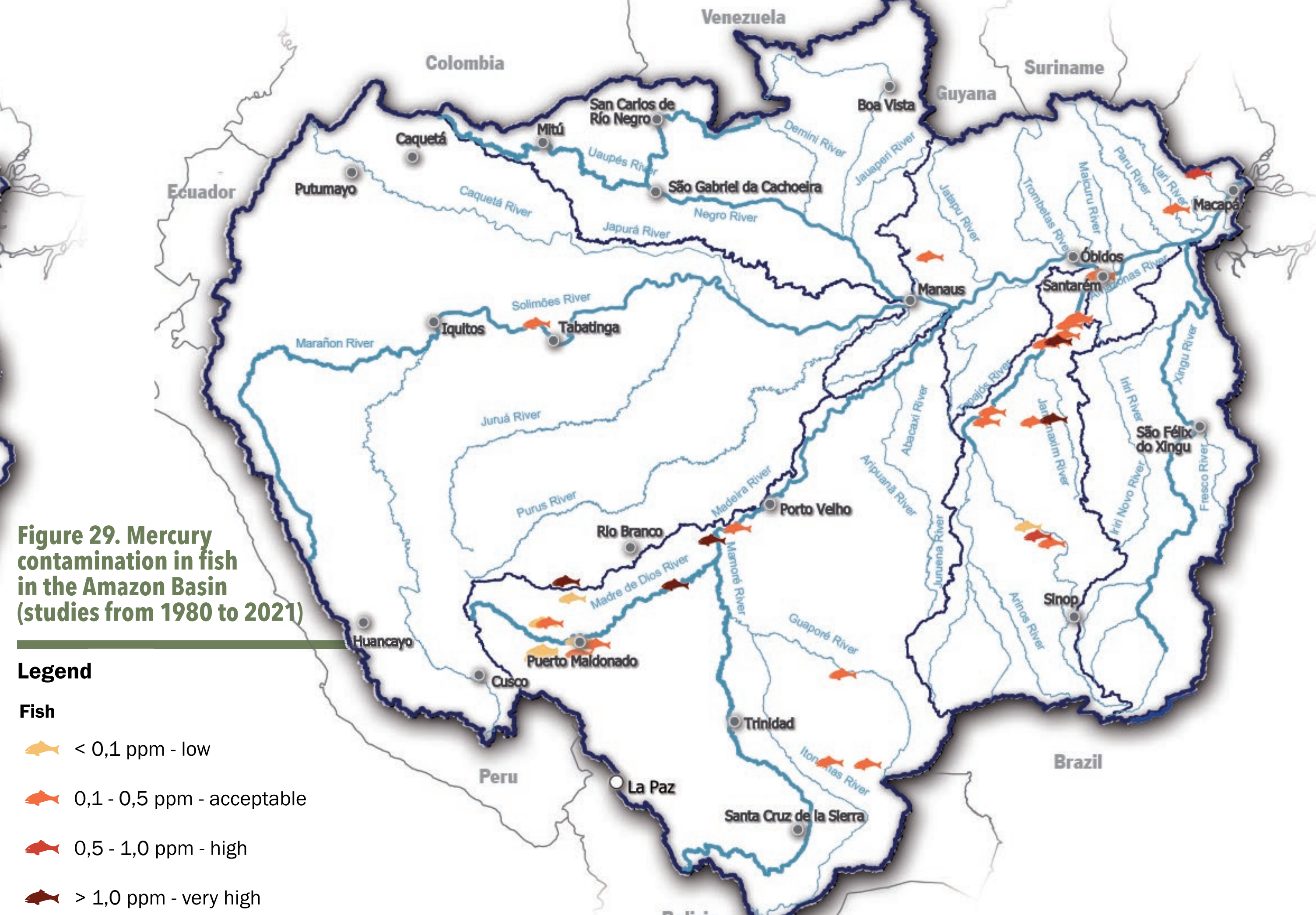


Figure 29. Mercury contamination in fish in the Amazon Basin (studies from 1980 to 2021)

Source: Observatório do Mercúrio na Amazonia (2021)

Machu Picchu | Peru | Wirestock Images on Freepik

Various civilizations and native peoples of the Amazon basin already had advanced water management technology centuries before the arrival of Europeans. The extensive network of canals, springs and the irrigation, drainage and erosion control systems established by the Inca Empire at Macchu Picchu are still impressive today (WRIGHT, K.R., 2021).

5. RESPONSES TO THE PRESSURES IDENTIFIED

The responses given by governments and society to the degradation in the quality of surface water in the Amazon involve a wide variety of actions related to public policies that generate laws, regulations, command and control actions, research, programs, projects, in addition to those actions related to the participation of the civil society and water-using sectors.

For the purpose of this study, some of the most significant responses to the main pressures in the Amazon Basin were synthesized and selected. It is emphasized that a "response" in the context of the Pressure-State-Response methodology is linked to the reduction of impacts from the pressures, but not necessarily to only one, since there may be a response to several pressures.

Moreover, considering the current database for the Amazon Basin, it was not possible to measure linearly how the responses listed here were directly reflected in the status of water quality, mainly because both pressures and responses often affect water quality indirectly or with a time lag that is difficult to measure without continuous monitoring on an adequate scale.

Some of these actions of regional scope are briefly described below. This is not an exhaustive analysis of all the actions related to surface water quality, but an attempt to synthesize the main actions. Besides these responses, actions to improve the monitoring of the water quality in the Amazon Basin are also presented.

Mining

The main problem related to mining in the Amazon Basin is the illegal gold mining that contaminates the rivers with mercury and sediments.

According to ACTO/UNEP (2018) it is necessary to promote studies on the impacts of mercury contamination in the Amazon Basin and implement recovery programsmes for areas degraded by garimpo activities.

With regard to studies conducted, the Mercury Observatory is an important initiative was the creation of the Mercury Observatory developed by WWF-Brazil, in partnership with Fiocruz, CINCIA and other institutions, which brings together studies and information on mercury contamination in the Amazon region and allows it to be viewed in georeferenced form.

Regarding agreements on the subject, the **Minamata Convention on Mercury** aims to protect the environment and human health from mercury emissions and compounds, establishing a series of measures to achieve this goal. Currently, the convention has 137 signatory countries and, among the countries that make up the Amazon Basin, only Venezuela is not part of it.

Three countries of the basin have acted more effectively in reducing the use of mercury, with the formulation of public policies based on the Minamata Convention: Peru, Colombia and recently Ecuador.

Peru has adopted an intersectoral action plan in order to comply with the premises of the convention and, among the measures adopted, are a bill to ban mercury extraction in its territory, the adoption of a national plan for small-scale artisanal mining and the definition of procedures for the import and export of mercury, in addition to working to improve the traceability of mercury entering the country illegally (INSTITUTO IGARAPÉ, 2021).

Colombia adopted Law No. 1,658/2013, which regulates the use and trade of mercury in all industrial activities and, under this law, has set a goal of eradicating the use of mercury in mining operations within five years. In addition, it adopted several measures to phase out the use of mercury, replacing it with clean technologies in all areas where it is used (INSTITUTO IGARAPÉ, 2021).

Ecuador created an action plan in 2020 specifically for artisanal and small-scale mining in the country, called the *"Plan de Acción Nacional sobre el uso de Mercurio en la Minería Artesanal y de Pequeña Escala de Oro en Ecuador Conforme la Convención de Minamata sobre Mercurio"*. The objective of this plan is to reduce or eliminate the use of mercury in the gold sector by defining strategic lines of work, actions and activities.

It is also important to note the initiative of Conservation Strategy (CSF) and the Brazilian Federal Public Ministry, with the creation of the "Illegal Gold Mining Impact Calculator", an analytical and pedagogical tool to describe the impacts of illegal gold mining, as well as the monetary values and the step-by-step process to measure them.

The Minamata Convention, if put into practice by all the countries of the Amazon Basin, will constitute an important response for the mitigation of the presence of mercury in Amazonian rivers.

Sanitation

The Amazon countries have legislation on sanitation in order to provide this important service to the populations. However, in general, the levels of sewage and solid waste collection and treatment are still low in the Amazon Basin.

Bolivia has a set of legal works that address environmental and sanitation issues, having established that sanitation services will be provided by state, public, community, cooperative or mixed companies.

Brazil has a National Water and Basic Sanitation Agency (ANA), which in 2020, with the amendment of the Sanitation Legal Framework, began to establish reference standards for sanitation services in the country, governed by Law No. 11,445/07. This Legal Framework, in addition to changing the agency's activities, established new guidelines for achieving the sector's goals by 2030.

In Colombia, the Constitution makes specific reference to sanitation, the financing of priority services and the well-being of the population with equitable access to water. Law No. 373/97 stipulates that every regional and municipal plan must incorporate a programe for the efficient use and saving of water, in line with projects adopted by water users and sanitation service providers.

Ecuador's Constitution states that the provincial governments are responsible for providing sanitation services, which means drinking water supply, sewerage and wastewater treatment.

Guyana does not have specific legislation for sanitation, but it has a Water and Sewerage Act, which is the regulatory framework with regard to development parameters of the national water policy. The Ministry of Housing and Water is linked to the issue of sanitation.

In Peru, the National Water Authority is the body responsible for managing and monitoring natural water sources, authorizing volumes of water abstracted by sanitation service providers, assessing environmental instruments, granting water use rights, authorizing the discharge of effluents and the reuse of treated wastewater, authorizing works on natural sources and running the National Water Resources Management System.

Finally, in Venezuela there is also no specific legislation on sanitation, however, its Carta Magna states that sanitation services are a municipal competence.

With regard to planning instruments, stands out the "Regional Action Plan for Drinking Water, Basic Sanitation and Solid Waste Management", which is being prepared by ACTO with IDB support.

ICAO Image Bank

Açaí Palm | ACTO Image Bank

Parrot Pair | ACTO Image Bank

This plan will identify critical areas and will present a regional information model analyzing each country and the region. It will also present recommendations for modernization, innovation and best practices, governance proposals and measures by country. Based on the information collected, the Transboundary Strategic Plan for the provision of drinking water, basic sanitation and solid waste services in the Amazon region will be developed with integrated action plans at national and regional levels such as water quality conservation plans, water safety plans, sanitation safety plans and the sharing of these plans with Member Countries.

ACTO/UNEP, through the document "Regional Transboundary Diagnostic Analysis of the Amazon Basin (2018)" highlights the actions needed to improve the sanitation situation in the basin. Among them it can be mentioned:

• Strengthen the technical, financial, and institutional capacities of the main actors in the basin through capacity building to mitigate water pollution and ensure effective participation in the management of the region's water resources;
• To establish guidelines for public policies at a regional level to make IWRM feasible in the Amazon Basin, aimed at tackling water pollution, promoting land planning, land use, forest and water ecosystem management, as well as promoting sustainable production practices;
• Promote policies and strategies for the protection and monitoring of water sources;
• Promote the revalorisation of knowledge, experiences and good practices of communities and local populations;
• Promote environmental education programs on the risks and impacts of water pollution.

Oil Exploration

Accidents in pipelines (operational failures, pipeline corrosion, etc.) are a significant source of contamination and require inspection and rapid response actions in the event of leaks, in addition to remediation of contaminated areas and compensation for affected populations.

In Ecuador, the company Petroecuador has been developing the Amazonia Viva Project since 2014 with the aim of remediating contamination through environmental clean-up and rehabilitation actions in areas affected by oil exploration. The actions involve soil decontamination and the elimination of pollution sources.

An Environmental Technology Research Centre was also created in this project, which works in coordination with universities in Ecuador to develop soil treatment technologies with microorganisms. The company has also created nurseries for the production of forest species and develops educational actions with the population of the affected areas (PETROECUADOR, 2018).

Another source of contamination in the oil industry is the water produced during the exploration process, which contains metals, chlorides and hydrocarbons. When discharged into soils and rivers these waters cause extensive contamination. In Peru a national legislation of 2009 established the obligation that the water produced in the oil exploration process be re-injected into the exploration well (Yusta, 2017).

According to ACTO/UNEP (2018) other direct causes of oil contamination are insufficient maintenance of pipelines, installations and vessels, pipeline vandalism, lack of training of technicians, and obsolete technology in exploration, also requiring a greater presence of the State in the environmental control of this activity and greater participation of communities affected by oil activity.

Deforestation and fires

The Amazonian countries have adopted command and control actions to act on occurrences of deforestation and fires.

Due to the large size of the Amazon Basin, it is necessary to use satellites to identify the affected areas and allow the generation of alerts for the inspection bodies.

In Brazil, the Burning Program developed by the National Institute for Space Research (INPE), since 1998, publishes daily information on the occurrence of fires in Brazil and other countries in South and Central America, with emphasis on the detection of active burning outbreaks in near-real-time by Earth observation satellites.

The Project for Monitoring Deforestation in the Legal Amazon by Satellite (PRODES), also developed by the National Institute for Space Research, has monitored deforestation by clear cutting in the Legal Amazon since 1988 and calculated the annual deforestation rates in the Brazilian Amazon.

Other mechanisms, such as the Soy Moratorium in Brazil established in 2006, collaborate to reduce deforestation. The main objective of the initiative of the Brazilian Association of Vegetable Oil Industries (ABIOVE) and the National Association of Cereal Exporters (ANEC) is to ensure that the soybean produced and commercialized in the Amazon is not associated with the suppression of the forest. The Moratorium does not restrain the expansion of soybean in the Amazon, but encourages its planting in open areas prior to 2008, avoiding the conversion of the forest to soybean.

According to ACTO/UNEP (2018), some actions are needed to reduce or mitigate these activities. Among them it can be mention:

• Promote the development and implementation of land use plans;
• Promote multilateral agreements to harmonize environmental and natural resources;
• Promote the development of guidelines for the mitigation and/or compensation of environmental impacts;
• Promote improved forest law enforcement and enforcement;
• Promote instruments of control, vigilance and inspection and incentives in forestry exploitation;
• Promote environmental audits in forest exploration areas;
• Promote compensation mechanisms for ecosystem functions/services for forest consumption;
• Promote mechanisms, programs and incentives for the conservation of native forests;
• Promote mechanisms for the participation of local communities and populations in land-use planning processes;
• Promote studies on the feasibility of an "agrosilvopastoral" system suitable for the type of soil affected by both deforestation and/or forest degradation.

Climate change

Climate change adaptation measures are essential for society to adapt to these events which are increasingly frequent and intense in the Amazon region with an increase in droughts and floods.

In this regard, an important action was the implementation of the Early Warning System in the MAP region covering the Madre de Dios (Peru), Acre (Brazil) and Pando (Bolivia) rivers.

Regarding the problem awareness, it is worth mentioning the Atlas of hydro-climatic vulnerability of the Amazon Basin (ACTO, 2021), which aims to contribute to knowledge of the Amazon territory, deepening aspects of socio-economic and physical vulnerability of the Amazon Region and the exposure of populations to extreme climate events such as droughts and floods.

According to ACTO/UNEP (2018), some actions are necessary to minimize the impacts of extreme climate events. Among them itcan be mentioned:

• Promote the monitoring of extreme hydrological events;
• Promote the expansion of hydro-meteorological network systems;
• Promote the implementation of early warning systems and risk management plans and disasters;
• Promote regional cooperation to mitigate the impacts of major infrastructure works;
• Foster regional cooperation to mitigate the impacts of climate variability and climate change;
• Promote land management plans;
• Promote incentive mechanisms for the protection and conservation of springs at the "watershed headwaters";
• Promote economic incentive mechanisms for forest conservation;
• Promote compensation programs and projects for ecosystem functions/services.

Waterways

Navigation is an essential for integration and regional development in the Amazon Basin. In recent years the waterways in the basin have shown a significant increase in cargo movement (grains, fuels, containers, etc.), especially in the Madeira River Basin.

In the dry season the rivers become shallower and strandings of boats are recorded that may result in accidents and pollution of the rivers. In these periods it is necessary to monitor the hydrology of the rivers and maintain river flows that allow safe navigation.

In order to manage this flow regime, it is necessary to establish a regional cooperation agreement for the management of the basin's water resources, considering the demands of navigation to maintain navigability conditions.

According to ACTO/UNEP (Regional Transboundary Analytical Diagnosis of the Amazon Basin), other causes of pollution caused by navigation are the informality of cargo and passenger transportation, non-compliance with safety norms and inadequate vessel maintenance practices. In this sense, it is necessary to implement river planning, improve inspection by the Port Authorities and investment policies in port structures.

Hydroelectric power plants

Investment in other types of renewable energy (such as wind and solar) by ACTO member countries could reduce the pressure to build hydroelectric dams in the Amazon region. These hydroelectric plants do not use large reservoirs and take advantage of the water force to generate energy without having to store large amounts of water. Accordingly, a smaller area is flooded, reducing the impacts on terrestrial ecosystems and water quality.

Examples of run-of-the-river hydroelectric plants are the Jirau HPP and the Santo Antônio HPP, both on the Madeira River in Brazil. The Water Quality Monitoring Program for the Madeira River, and its tributaries carried out since 2009 by the Santo Antônio Energia Company along a 300-kilometer stretch is a good example of monitoring associated with hydroelectric projects.

According to ACTO/UNEP (2018), some actions are necessary to minimize the impacts related to large infrastructure works. Among them it can be mentioned:

• Promote land use plans and programs;
• Promote mechanisms to strengthen national control agencies and institutions, environmental monitoring, and inspection;
• Promote mechanisms to integrate the planning cycle of large projects into the national planning process, including reviews and approvals at each project phase;
• Promote mechanisms for regional coordination and harmonization of national planning instruments;
• Promote mechanisms for transparency and information on individual megaprojects throughout their maturation and in the planning process;
• Promote programs and projects for the implementation of monitoring systems for impacts of large infrastructures;
• Promote financial compensation mechanisms for communities and populations sites affected by the impacts of major infrastructures;
• Promote studies and research on the impacts of large infrastructure works.

Agriculture and Livestock

The adoption of agricultural and livestock practices that reduce water contamination, such as preventing soil erosion by adopting management practices and the correct use of fertilizers and pesticides, is essential to reduce the impacts on the quality of water bodies.

The implementation of payment for environmental services policies, through incentives to farmers for the recovery and maintenance of forest remnants, can contribute to reducing the impact of these activities.

According to ACTO/UNEP the following actions are necessary to reduce the impact of agropastoralism in the Amazon Basin:

• Promote programs and projects for the recovery of degraded soils and ecosystems;
• Promotion of agroforestry production systems on land suitable for forestry and recuperation of degraded forests;
• Promote programs and projects to make use of alluvial soils suitable for agriculture;
• Promotion of programs and projects to combat soil erosion resulting from deforestation on slopes and poor soil management;
• Promotion of programs and projects for the conservation of more fertile soils in the lowlands alluvial ("várzeas");
• Promote studies and research on soil hydraulic services;
• Promote studies and research on the characteristics and potentialities of soil use non alluvial on sandbanks, high terraces, hills, and mountains;
• Promote environmental investments and businesses by strengthening local communities and organizations for the appropriation and application of sustainable environmental practices.

Amazon River | Itacoatiara - Brazil | Abobe Stock Image Bank

Water quality monitoring

Regional Network for Monitoring Surface Water Quality

The Regional Network for Monitoring the Quality of Surface Waters for the Amazon Region (RR-MQA), illustrated in Figure 30, whose project was recently approved by the Member Countries of ACTO, is a response of great impact on water quality, since it will establish monitoring with spatial and temporal representativeness, measuring the measurement of the same parameters in the different countries, and considering identical sample collection and analysis methods, which is expected to be a milestone for the advancement of water resource management in the Amazon Basin.

Once the network is completed, 111 monitoring points will be installed in three different phases for the monitoring of the water quality in the Amazon Basin, facilitating shared management. At the beginning of the operation, the monitoring parameters will be pH, electrical conductivity, dissolved oxygen, temperature, total dissolved solids, total suspended solids, turbidity, ammoniacal nitrogen, nitrate, total phosphorus, and orthophosphate. In the second phase, water quality parameters such as COD, BOD, coliforms, chlorophylla, heavy metals, among others, will be analyzed.

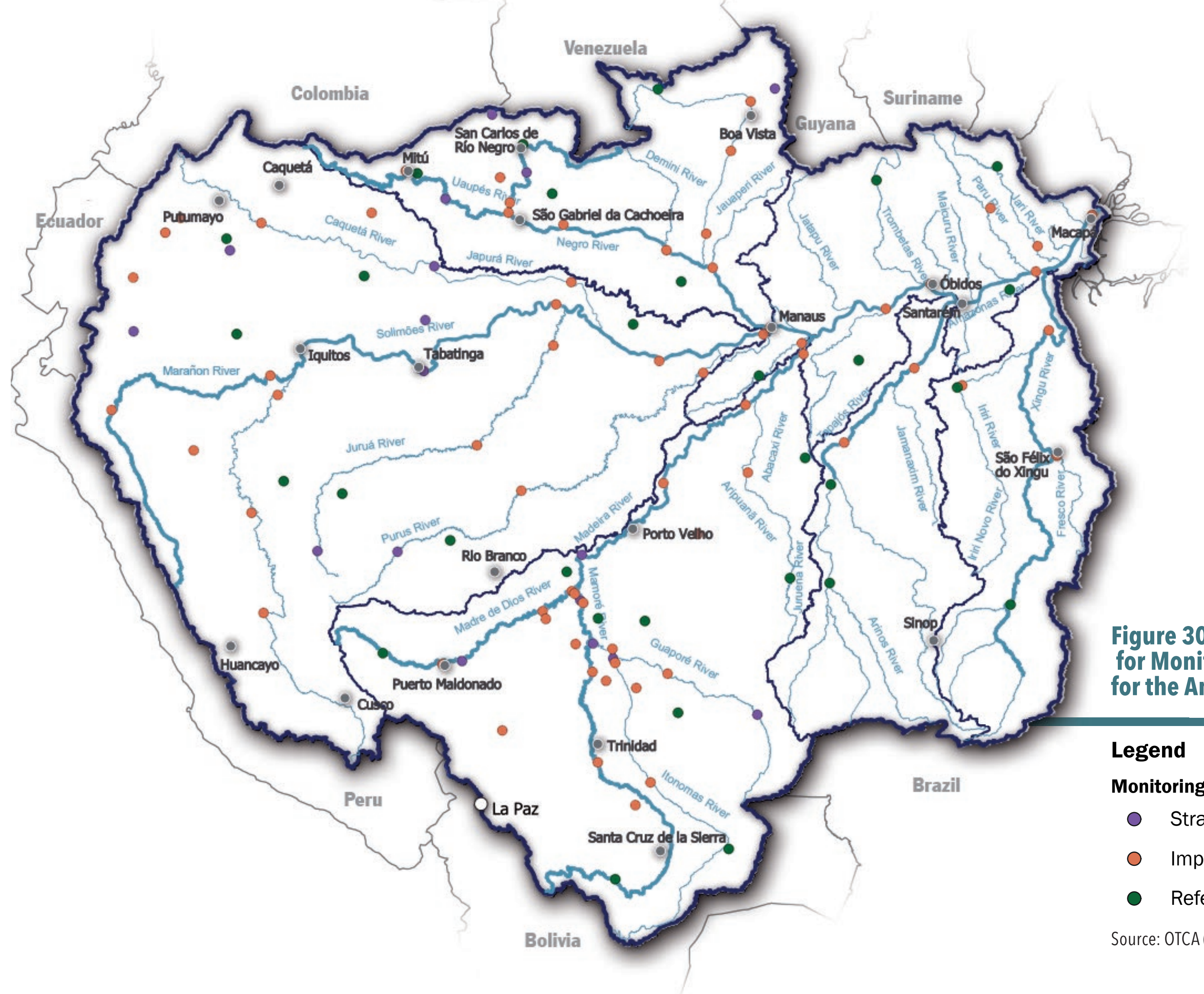


Figure 30. Proposal of the Regional Network for Monitoring the Quality of Surface Waters for the Amazon Region (RR-MQA)

Legend

Monitoring Points

- Strategic
- Impact
- Reference

Source: OTCA (2021).

Amazon Regional Observatory

The Amazon Regional Observatory (ARO) is the result of the initiative of 8 Amazonian countries (Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, Suriname and Venezuela). This initiative is being promoted in the framework of the cooperation exercised by the Amazon Cooperation Treaty Organization based on the postulates of the Amazon Cooperation Treaty signed by the Member Countries in 1978.

Based on the first definition of the ARO at the XII Meeting of ACTO Ministries of Foreign Affairs (2013), and taking into consideration the elements outlined in the conceptual design, the definition of the observatory was updated, expanding its scope under the Vision of being a Reference Centre for Information on the Amazon and a permanent Virtual Forum that promotes the flow and exchange of information between institutions, public authorities, the scientific community, academia and civil society of the Amazon countries.

Its Mission is to "collect, process, organize and disseminate information from the Amazon in a comprehensive and comparable manner on the themes established in the ACTO's Amazonian Strategic Cooperation Agenda (ASCA), providing information services to the governmental and non-governmental scientific community and civil society for the study and development of the Amazon".

The ARO emerges as a technological mechanism that seeks to generate responses and inputs for national and regional decision making in the face of latent emergencies, such as fires, floods, extreme weather events, etc., as well as growing and recurring problems related to deforestation, droughts, illegal mining, agriculture, basic sanitation, oil exploration and use, waterways and hydroelectric power plants, climate change, trafficking of biodiversity species, etc. The ARO will provide early warning and relevant information for the authorities to carry out relevant actions.

The Observatory is supported by a functional IT structure, with access through a web portal (https:// oraotca.org/), and its operation is based on an information value chain that includes the processes of obtaining and loading information, as well as the homogenization, storage, filtering, processing, consultation and downloading of data. ARO's functional structure enables modular information organization, organized into thematic and integrating modules. These modules have their respective functions, products, and services, so as to enable an adequate management of Amazonian knowledge.

The information published in ARO comes from various government agencies of the Member Countries and also from external sources, such as regional and international bodies, which are highly regarded for their work in the Amazon.

The themes prioritized in ARO are linked to the ASCA agenda and so far the thematic modules related to CITES Species and Biodiversity have been developed, and those related to Forests, Water Resources and Indigenous Peoples are being concluded, as well as the construction of the MIPYMES modules, as well as the RedCIA and Climate Change.

The integrator modules are designed to provide integrated services for consulting information on specialized themes and sub-themes, which are presented through different visualization tools, depending on the purpose of the communication and the associated format.

In the Geoamazonia Module, information is presented on a regional scale, through a geovisor, which allows different layers of information to be superimposed and which is fed by a catalogue of maps from official and non-official sources, organized into different categories, themes and sub-themes.

In the Water Resources Module its possible to verify the thematic maps of climatological variables (Precipitation, Evapotranspiration, Temperature) and the studies of the hydrological characteristics of the region (channels, flood zone, among others). As in the other modules available in geovisor, maps and information on water resources can overlap among themselves and with any other module.

The Amazon Networks Module articulates information from different monitoring networks established in the region that generate official data for water resource management in Member Countries, such as the Amazon Hydrological Network (RHA), the HYBAM Station Network and the Water Quality Monitoring Network.

The ARO has a Situation Room that houses the Amazon Hydrological Network (RHA) and the Regional Water Quality Monitoring Network (RR-MCA) of the ACTO to systematically monitor various aspects related to water resources and critical events at the Amazon regional level.

Thus, the ARO, through its various available information sources and with the available tools, will allow the follow-up/monitoring of the different sources of pressure (floods, droughts, fires, among others) as well as the cross-referencing of different information that allows a detailed analysis of the sources of pressure, subsidising decision-making by Member Countries for the prevention and/or mitigation of the different impacts on water quality.

6. GENERAL OVERVIEW

Manaus - Brazil | Adobe Stock Image Bank

6.1. CRITICAL AREAS

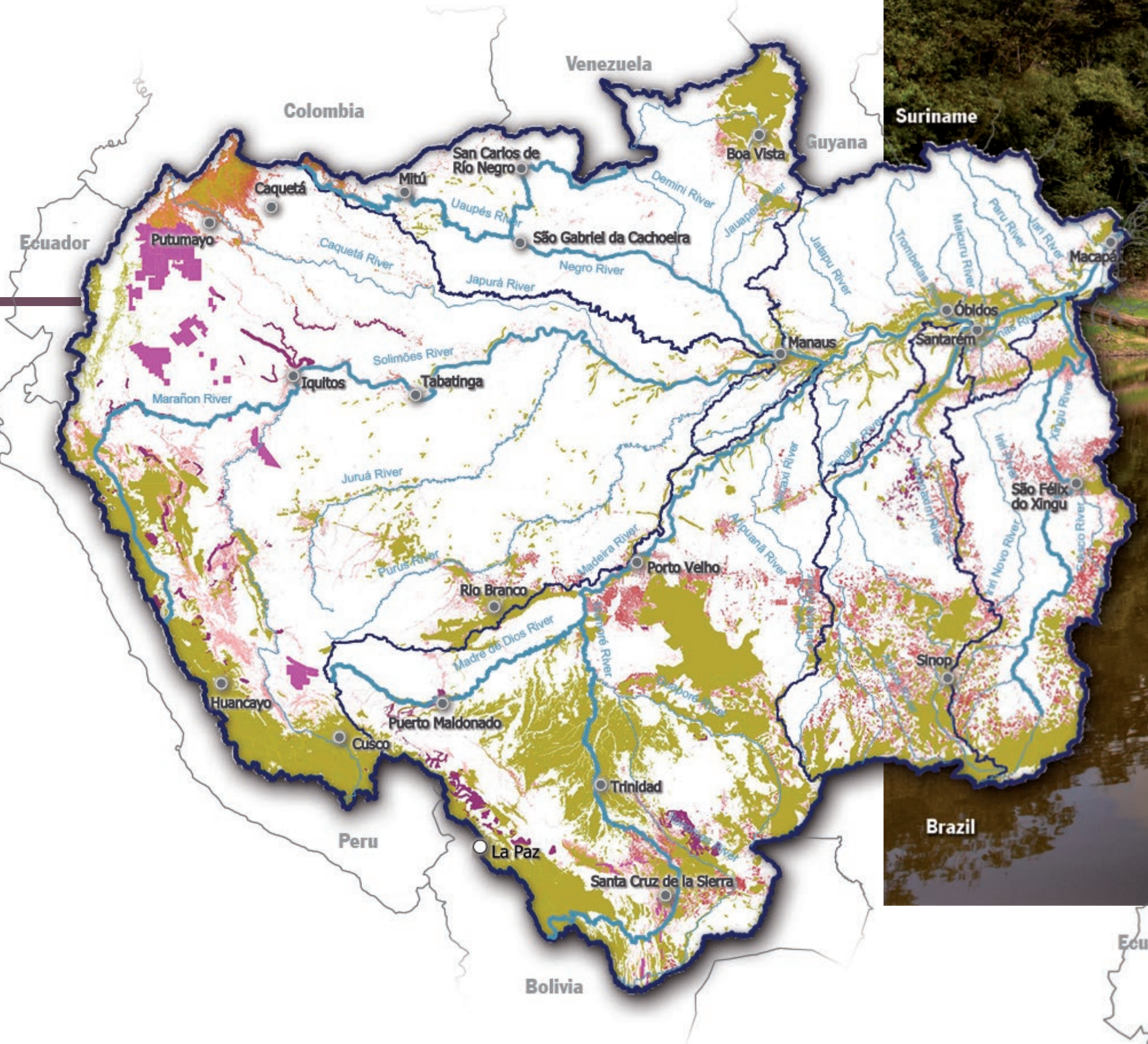


Figure 31. Critical areas in terms of pressures

Legend
- Agropastoral Areas
- Deforestation
- Oil Plots
- Mining

Source: Cobrape (2022).

Considering the existing data, and its heterogeneity in terms of time, space, and monitored parameters, no specific critical areas of water quality could be proposed. Therefore, from the application of the PER methodology, especially based on the pressures identified, regions that can be considered critical in terms of susceptibility to water quality degradation were defined, based on five approaches, shown in the following figures:

- Pressures: comprise areas of deforestation, mining (exploitation), oil lots (exploitation) and areas of agriculture and livestock surveyed in this study and which alone represent potentially critical areas (Figure 31);
- Pressures in special areas: comprise the result of the overlaps of the pressures already mentioned with the areas considered special: Protected Areas, Indigenous Territories and flood zones (Figure 32);

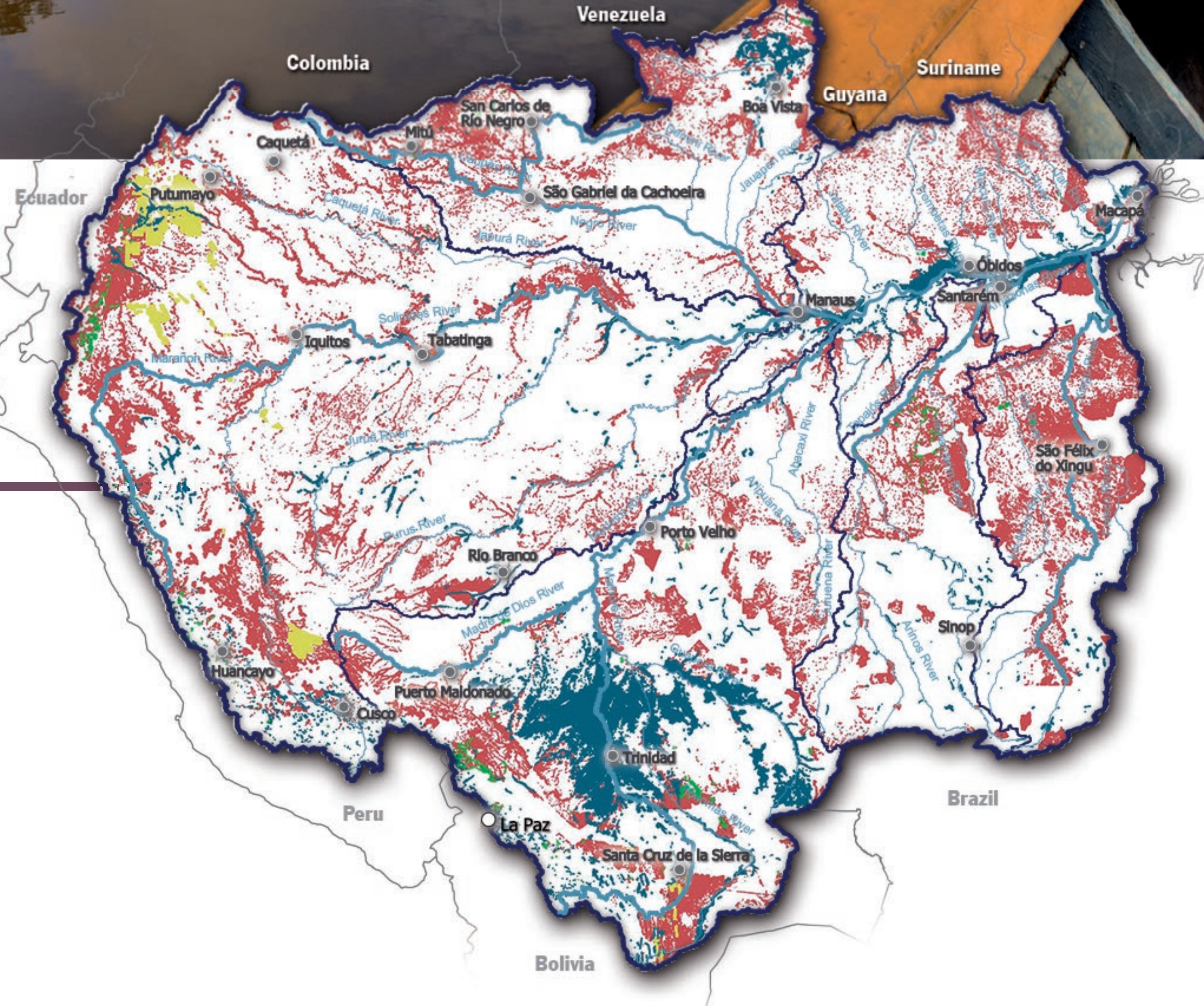


Figure 32. Critical areas in terms of pressures in special areas

Legend
- Deforestation areas in Protected Areas and Indigenous Territories
- Oil Allotments in Protected Areas and Indigenous Territories
- Mining Areas in Protected Areas and Indigenous Territories
- Areas of farming and livestock in flood zones

Source: Cobrape (2022).

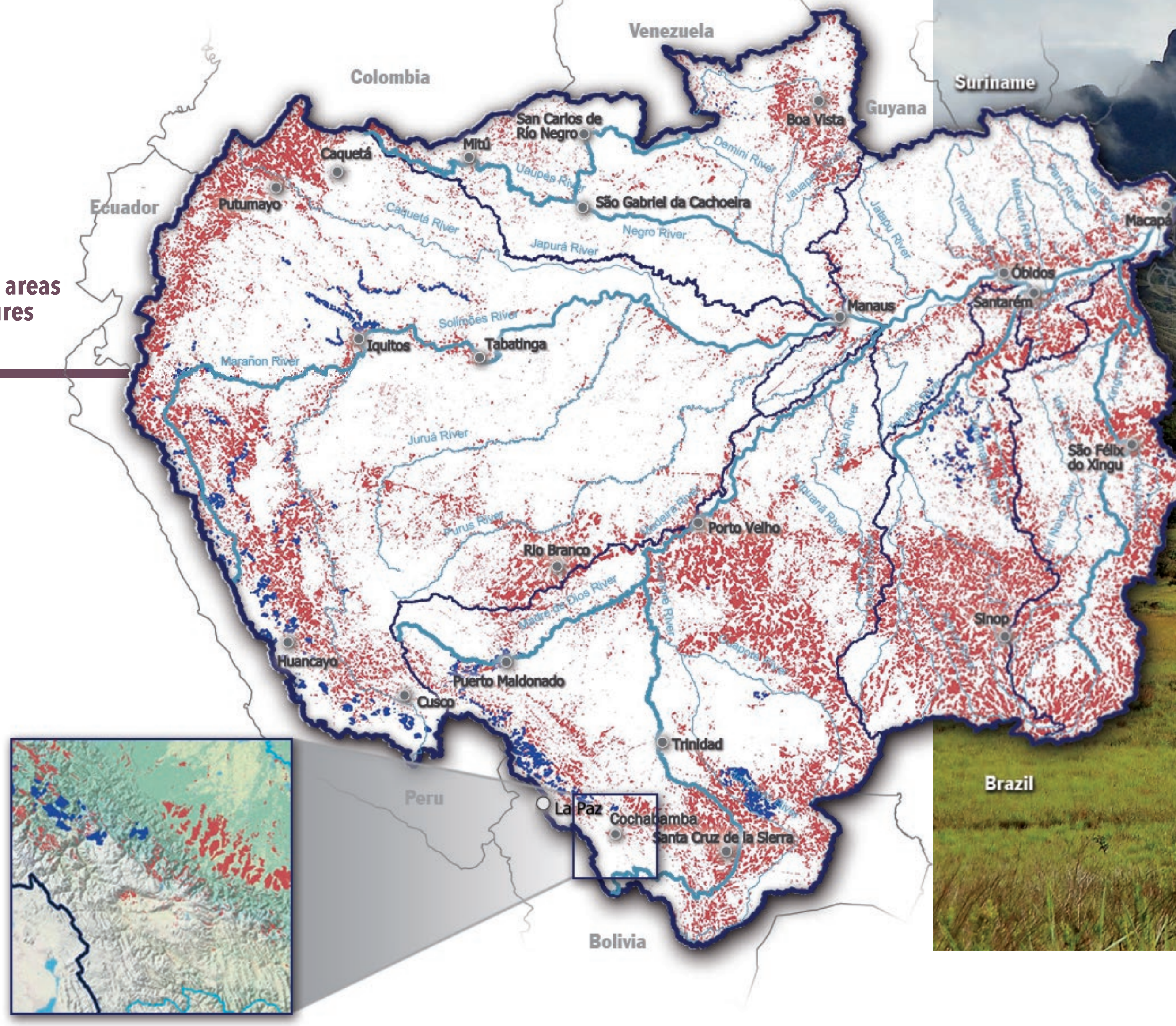


Figure 33. Critical areas in terms of pressures in headwaters

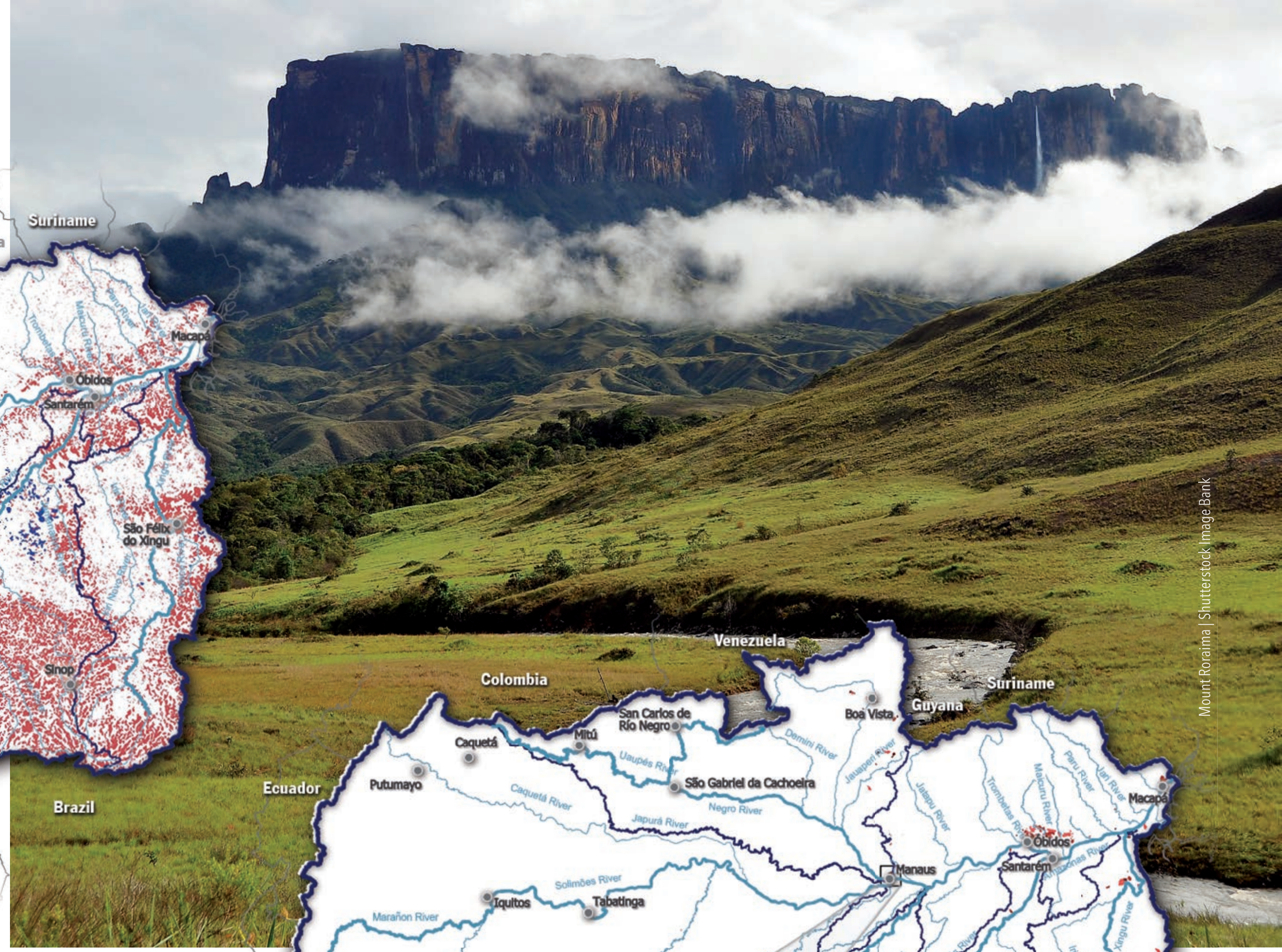
Legend
- Deforestation
- Illegal Mining

Source: Cobrape (2022).

- Pressures in headwaters: comprise the areas resulting from the crossing of deforestation and illegal mining areas with the headwaters identified in the hydrographic base (Figure 33);
- POPI (Potential Organic Pollution Indicator): comprise the areas where the estimated POPI corresponds to the "Regular", "Poor" or "Bad" ranges (Figure 34);
- Mercury: comprise the areas resulting from the crossing of historical monitoring data (1980- 2001) with high concentrations of mercury, in humans and fish, with drainage areas with mining (legal and illegal) (Figure 35).

The figures show that the pressures are distributed throughout the sub-basins of the ARB, notably present in headwaters and special areas, especially in indigenous territories. This situation is generally of concern, since in these areas there is usually no monitoring of water quality, and traditional communities usually consume water without prior treatment.

Although agriculture and livestock stood out in terms of occupied area, the significant impact of mining was evident - two pressures that can be associated with a third pressure:



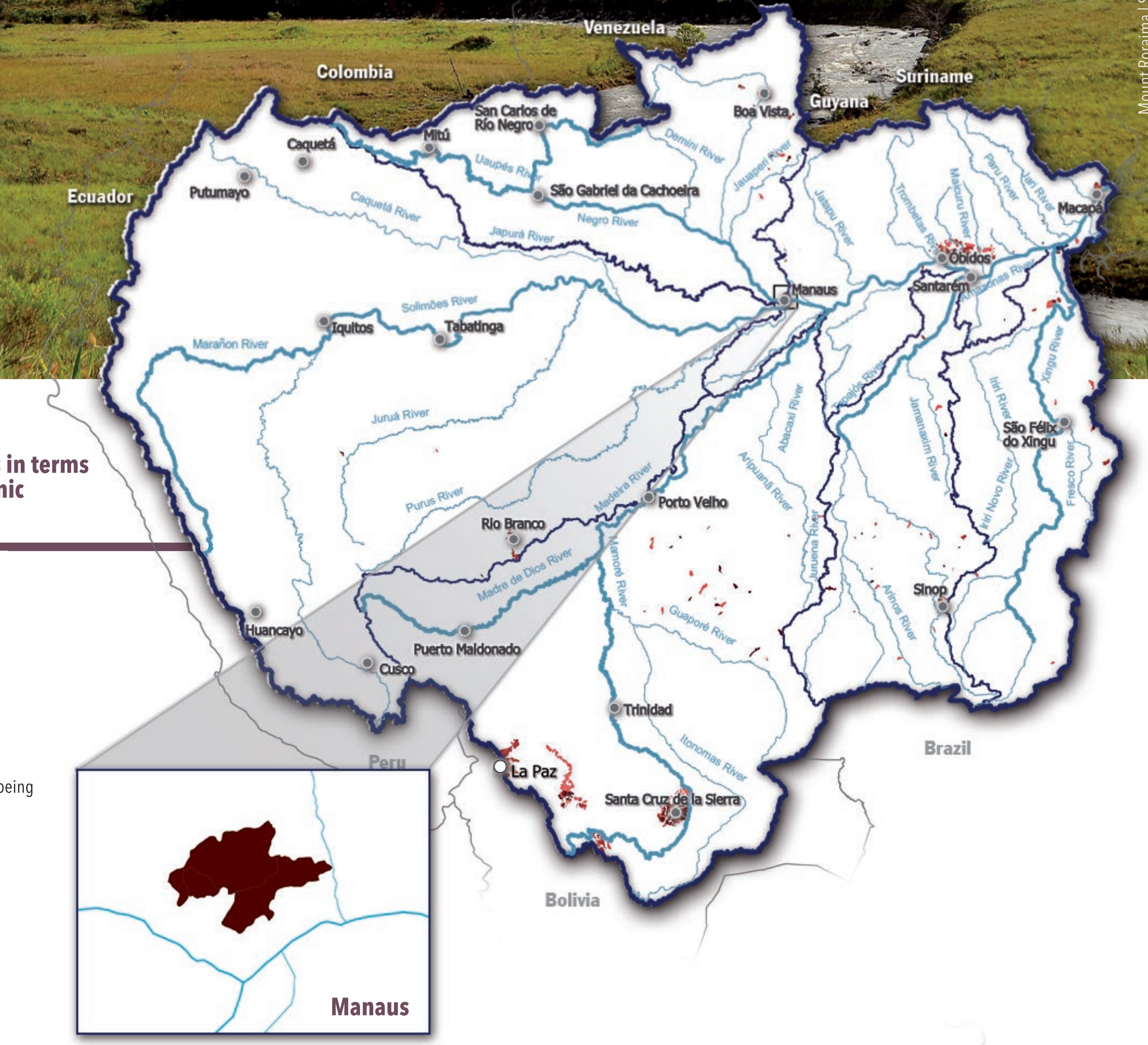


Figure 34. Critical areas in terms of POPI (Potential Organic Pollution Indicator)

Legend

Situation
- POPI Regular
- POPI Poor
- POPI Bad

Note: ranges defined based on the legislation of Amazonian countries, being specific for this study.

Source: Cobrape (2022).

deforestation. This is normally the initial stage of alteration. This is normally the initial stage of other activities, and which indicated alterations in water quality, especially in the parameter electrical conductivity, directly linked to the hydrogeochemical characteristics of Amazonian rivers.

The advance of mining, which leaves the population vulnerable to water-borne diseases and generates contamination of water bodies, especially by mercury, as well as diffuse pollution from agriculture, pastures, oil exploration and hydroelectric plants also end up affecting the population, which depends on good quality water for various activities such as fishing, subsistence farming, domestic supply, among others.

Urban areas with large population contingents and small rivers were evident in the analysis of critical POPI (Figure 34), especially the municipalities of Manaus, in the Lower Amazon sub-basin, and Santa Cruz de La Sierra and Cochabamba, both in the Madre de Dios/Madeira/Mamoré sub-basin.

With regard to mercury, large regions stand out in the Tapajós, Madre de Dios/Madeira/Mamoré sub-basins and in the most upstream region of the lower Amazon sub-basin (Figure 35). More spatially distributed regions, but also in significant areas, are observed in the Marañon/Solimões sub-basin, in the headwater regions and near Iquitos (Peru).

In general, the analysis shows that the water quality in a considerable part of the Amazonian rivers can be considered good, but the influence of mining activities, agriculture and urban occupation was evident in many of the sub-basins. This was demonstrated through the application of a methodology that relates the pressures with alterations in water quality. The need for adequate monitoring is also highlighted, so that this relationship can occur more accurately enabling measures to be taken regarding the pressures that in fact have an impact on the quality of the water bodies.

Other problems related to water quality include the lack of sanitary sewage collection and treatment - especially in urban centres - and the undue occupation of preservation areas, which are caused mainly by the lack of urban planning combined with the disrespect for environmental legislation. This scenario accentuates several problems such as leaching from degraded areas and the deforestation of the riparian forest and soil erosion, which increase the concentration of pollutants in rivers located around cities.

It must be emphasized that few rivers had their hydrogeochemical characteristics established, and that the criterion of analysis of the legal limits considering the most and least restrictive, had very discrepant values between each other. This reinforces the importance of defining water quality standards for Amazonian rivers based on the natural characteristics of these rivers, with the differentiation of hydrogeochemical characteristics.

It is also worth mentioning the issue of climate change, whose most apparent and significant effects on the ARB are related to droughts, which, in terms of water quality, damage the oxygenation of water bodies, and floods, mainly affecting riverside populations, bringing water-borne diseases, as well as causing human and material losses.

Another very significant effect resulting from climate change is the melting of Andean glaciers, which is extreme in some places, as was the case of the Chacaltaya glacier that disappeared from the Bolivian landscape in 2009, after a number of years of shrinking. Peru concentrates around 70% of all tropical ice, and has lost around 25% of its glaciers in the last decade. The knowledge about the impacts that the melting of glaciers may cause is still incipient; however, rivers like Madeira and Solimões, which are formed from the contribution of glaciers from the eastern portion of the Andes, may be affected. If the contributions of sediments that fertilize these large rivers decrease in the coming decades, there is a risk of damage to ecosystems (ZORZETTO, 2013).

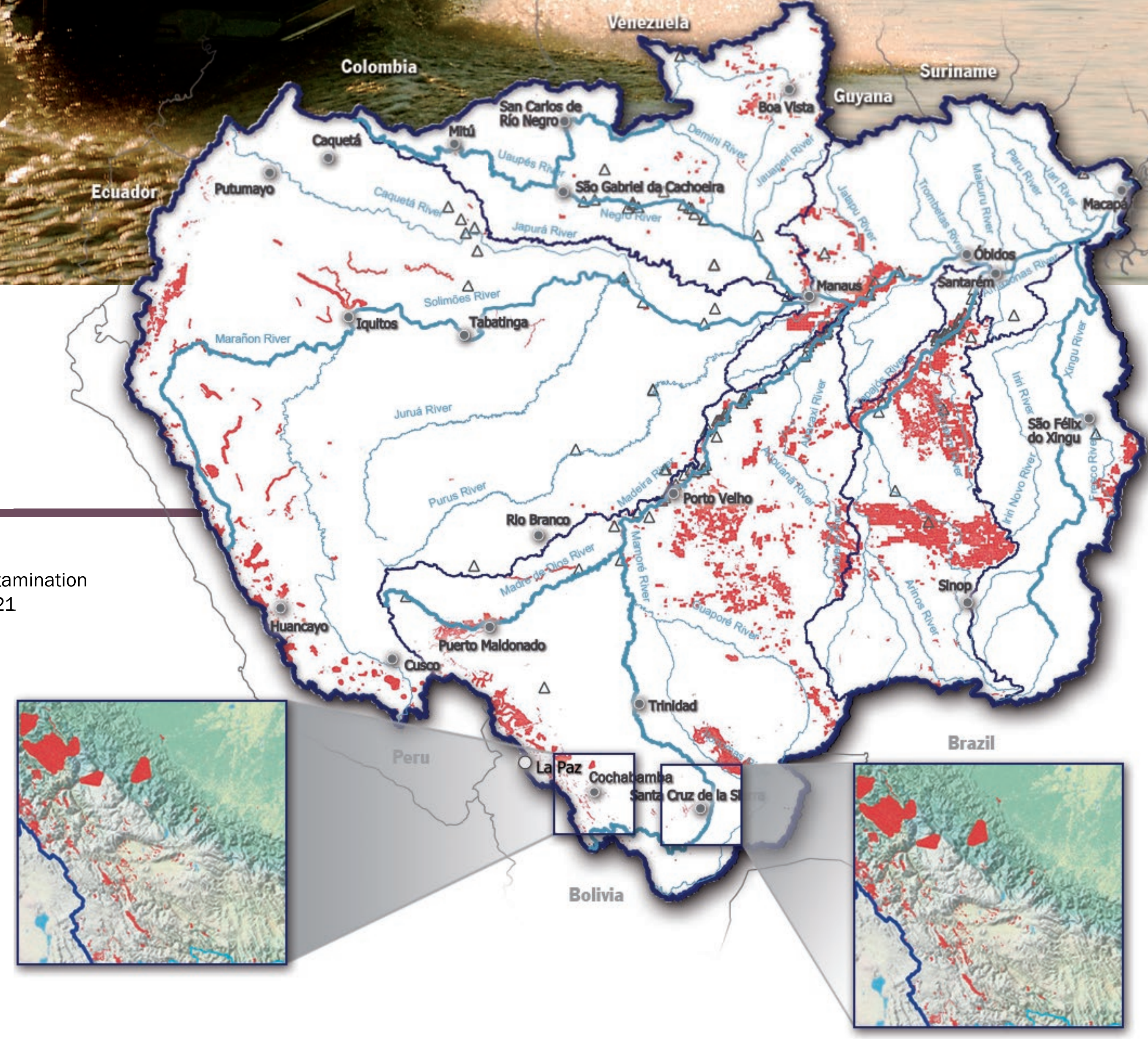


Figure 35. Mercury hotspots

Legend

△ Sites with recorded elevated mercury contamination in fish and people between 1980 and 2021

Illegal mining areas upstream of the sites with high Contamination

Source: Cobrape (2022).

6.2. PROPOSAL FOR INTEGRAL MANAGEMENT OF WATER QUALITY IN THE AMAZON BASIN

The elaboration of the **Proposal for the integral management of the water quality of the Amazon Basin** had its starting point in the analysis of the water quality monitoring data received from the Member Countries.

The obstacles related to the issue of water quality monitoring and good practices identified through the application of the PER methodology were validated with Member Countries, first through questionnaires, and then through online interviews with entities representing each of the countries. The interviews confirmed the deficiencies found through the technical analysis and provided further input for the structuring of the Proposal.

The proposal was developed in four phases. The first phase incorporated the specific measures and actions developed at the sub-national, national and intergovernmental cooperation levels of ACTO, articulated with the visions of the Amazonian Strategic Cooperation Agenda and the Strategic Action Program. In the second phase, experiences in water quality management for the Mekong, Rhine and Danube rivers were presented and discussed. In the third phase, contributions from Member Countries were received through a question-and-answer system in the format of a questionnaire. Finally, in the fourth phase, interviews were held with all to gather suggestions.

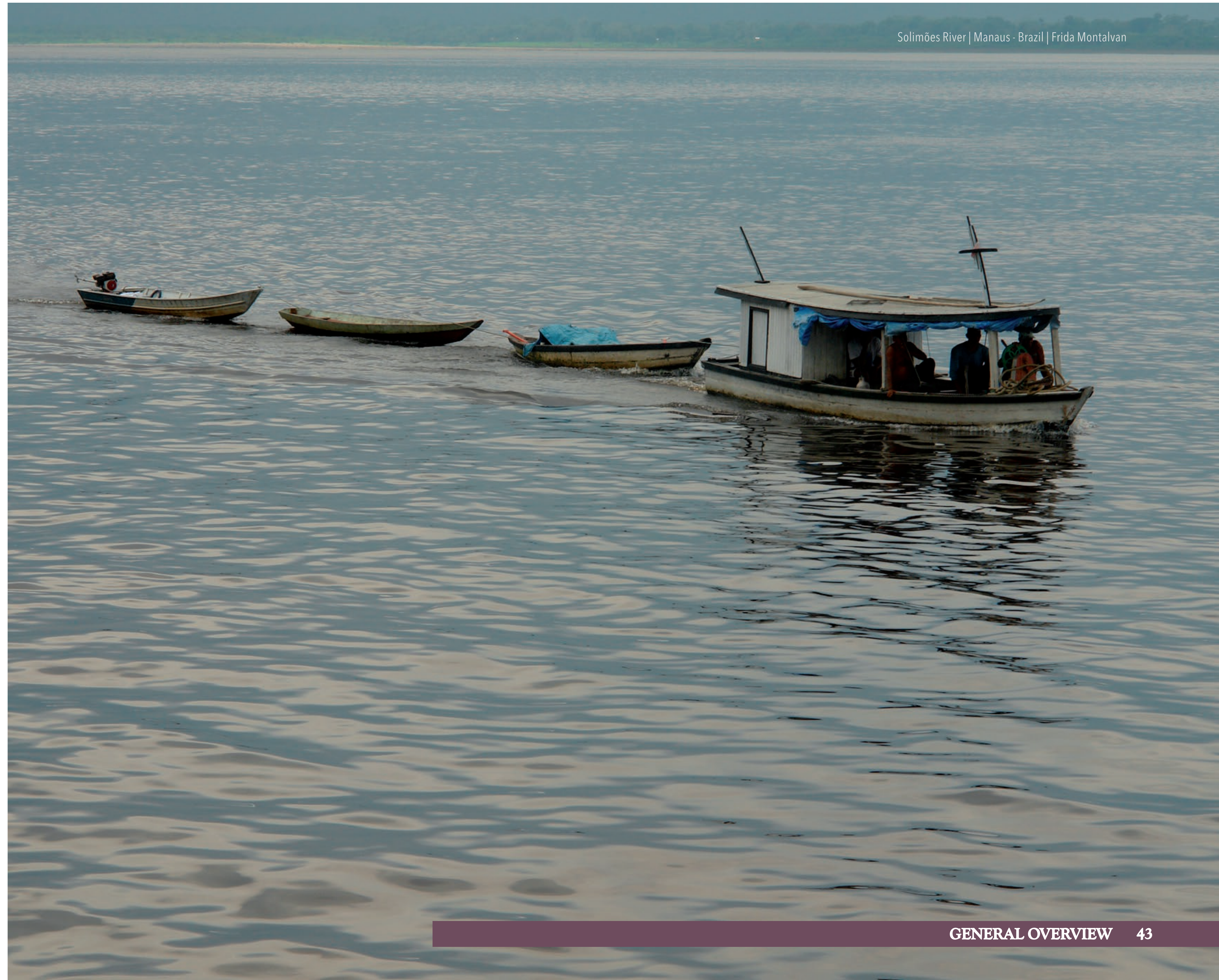
The *Mekong Agreement and Procedures* (1995) document, which deals with cooperation protocols adopted in this hydrographic basin, was used as a guide to consolidate the proposal. The choice of the Mekong River basin was due to its organization, the broad access to its documents and, above all, the high quality work developed by the *Mekong River Commission* (MRC).

In this context, the **Proposal for the integral management of the water quality in the Amazon Basin** is materialized in the creation of three Cooperation Protocols:

- First Protocol: aims at the exchange and sharing of information among the Member Countries of ACTO. Its specific objectives are (i) to operationalize the exchange and sharing of water quality information between the Member Countries; (ii) to make available the basic data and information as determined by Member Countries; and (iii) to promote mutual understanding and cooperation among Member Countries in the monitoring and conservation of water quality in the Amazon region;
- Second Protocol: deals with the monitoring of water quality. Its objectives are (i) to provide a broad and flexible framework to facilitate the implementation of water quality monitoring in the Amazon region; and (ii) to promote better understanding and cooperation among Member Countries in the water quality monitoring system of the Amazon region;
- Third Protocol: deals with the institutional framework for managing water quality at levels agreed upon by the countries. Its objective is to establish a cooperative framework for the protection and maintenance of good water quality in the Amazon region at levels agreed upon by the Member Countries.

Each of the protocols also has specific proposed articles dealing with their principles, the minimum content for water quality management, as well as indications for the integral management of water quality among all of the member countries of ACTO.

In short, it is expected that the protocols will be able to support this process and thus mitigate the adverse effects of pressures on water quality. It is known that, although they have great potential, there is the challenge of their actual adoption, which requires time and increasingly cooperative action among Member Countries.



6.3. CHALLENGES FOR WATER QUALITY MANAGEMENT IN THE AMAZON BASIN

One of the major results of applying the PSR (Pressure-State-Response) methodology was the identification that adequate information, both spatially and temporally, is needed in order for the pressure-state-response relationship to be analyzed more accurately. It would make it easier to identify how the pressures are altering aspects of water quality and the possible consequences for the biota and the human population. Furthermore, it would be possible to list which actions have brought good results to improve this issue, allowing for more correct decision-making.

More specifically about water quality monitoring, several bottlenecks were identified, such as: continuous production and deepening of information on water resources; more robust water quality monitoring in spatial and temporal terms; monitoring focused on defining the natural characteristics of the different types of Amazonian rivers; monitoring focused on the impact of the main pressures; common protocols for sample collection and analysis; procedure for data consolidation and availability.

Some of these aspects being resolved through the actions developed within the scope of ACTO's activities, such as the implementation of the Water Quality Monitoring Network and the protocols for sample collection and analysis. However, it is known that between the elaboration of these proposals, the agreement reached and the action itself, there are still many challenges, both in technical, financial, and political terms. Also, among the challenging advances identified, is satellite monitoring, which began in the basin, but requires continuity and expansion, along with partnerships and investments.

The lack of geospatial information was also noted that would facilitate the identification of the impact of domestic and industrial effluents on water bodies. Although the effects in small rivers are usually more local, depending on the composition and quantity, they can spread and bring damage to water quality and human health on larger scales. For a more detailed analysis of these problems, each country should possess and share this

information on a common basis, in a great challenge of compatibility.

Thus, the implementation of the Amazon Regional Observatory has been prioritized by ACTO as a space for articulation in different areas of information of the Amazonian countries. This observatory compiles, stores and publishes the data coming from different governmental entities of the Member Countries or, better yet, from the National Information Systems.

The mining activity was one of the most significant pressures identified and there are several studies published on this topic, however, they are usually developed by different institutions and on a small scale. The Mercury Observatory may be considered a good practice in this context, as it seeks to integrate this information. Considering the damage to health and the environment associated with the presence of metals in water, a major challenge for management in the ARB is to monitor more accurately this impact in order to plan mitigation actions in an activity that can grow, given the region's potential. Still on this aspect, it is worth mentioning the advance of illegal mining activities and the need for joint action by the different institutions of the Member States to combat this harmful practice to the environment and the health of the population, especially the traditional ones.

One of the challenges involved in the qualitative management of the Amazonian rivers is the definition of common standards to be followed by all the countries that have territory in the basin. This process requires building a discussion forum supported by technical analysis and allowing for adequate deliberation on what can be considered to be good quality water according to the uses.

Still in this regard, it is important to stress the need to consider the natural conditions of the rivers when defining these standards, given the significant hydrogeochemical differences observed. This also involves the differences in the physical and vegetation environment, citing the peculiarity of floodable areas, in which the water quality conditions are quite different. This process encompasses a better understanding of the natural conditions so that they can be included in the definition of water quality assessment standards.

This first Report on the Status of Water Quality in the Amazon Basin has brought an integrated view of the pressures, states, and responses, taking into account different data sources. It is therefore a first step, but at the same time an advance for quality management in the Basin. Many gaps were identified, demonstrating the importance of similar studies being carried out and pointing out solutions to major management challenges that involve the institutions and the need for continuous actions with long-term funding.

Considering all the richness of the Amazon resources and its cultural singularities, building this shared management is important so the problems identified can be mitigated and actions to better deal with emerging problems, such as climate change, can be structured to ensure appropriate water quality for the rivers and the population that depends on it.

Sunset over the Amazon River | ACTO Image Bank

TABLE OF PRIMARY SOURCES

Item	Theme	Source
1	Protected Natural Areas	"Servicio Nacional de Áreas Protegidas (SERNAP), 2015; ISA, 2020, a partir de los documentos oficiales; Digital Map Parques Nacionales Naturales según la categoría. Scale 1:100,000.República de Colombia. Parques Nacionales Naturales de Colombia 2019; Ministerio de Ambiente y Agua del Ecuador (MAAE, 2020); DCW; DEAL, 2007; Ministerio del Ambiente (MINAM)-Servicio Nacional de Áreas Naturales Protegidas por el Estado (SERNANP), 2019; World Database Protected Areas (WDPA), 2006; Provita, 2020, a partir de gacetas oficiales."
2	Indigenous Lands	"Instituto Nacional de Reforma Agraria (INRA), 2018; ISA, 2020, a partir de los documentos oficiales; Digital Map of Indigenous Reserves. Republic of Colombia. Agencia Nacional de Tierras 2019; Cover de EcoCiencia, 2019; Indigenous Affair/Gobierno de la Guyana, 2009; DEAL, 2007; Native communities: IBC-SICNA 2019; Campesino communities: SICCAM-IBC/CEPES, 2019; Indigenous reserves (creadas y propuestas): Ministerio de Cultura, 2019; Freire, G., Tillet, A. 2007. Salud Indígena en Venezuela. Mapa general. Ediciones de la Dirección de Salud Indígena, Caracas, Venezuela. - MPP Ambiente y MPP Pueblos Indígenas 2014. Mapa Tierras Indígenas. Dir. Gen. POT / Sec. Tec. Com. Nac. Demarcación del Hábitat y Tierra de los Pueblos y Comunidades Indígenas. Caracas, Venezuela. - Wataniba 2019 (en trabajo conjunto con organizaciones indígenas Oipus, HOY, Kuyunu, Kuyukani, Kuyujani originario, Kubawy)."
3	Deforestation	Collection of annual deforestation maps generated by RAISG, 2020, based on MapBiomas Amazonia Land Cover and Use maps (2001-2018), an initiative led by RAISG.
4	Mining	"Servicio Nacional de Geología y Técnico de Minas (SERGETECMIN), 2013; DNPM, 2020; Catastro minero digital de la república de Colombia. Agencia Nacional de Minería, 2019; Agencia de Regulación y Control Minero, (ARCOM, 2019); Instituto Geológico, Minero y Metalúrgico - INGEMMET, 2019; Ministerio de Energía y Minas, 2017."
5	Illegal Mining	"Servicio Nacional de Geología y Técnico de Minas (SERGETECMIN), 2013; DNPM, 2020; Catastro minero digital de la república de Colombia. Agencia Nacional de Minería, 2019; Agencia de Regulación y Control Minero, (ARCOM, 2019); Instituto Geológico, Minero y Metalúrgico - INGEMMET, 2019; Ministerio de Energía y Minas, 2017."
6	Farming	"Extracted from the annual (2001 and 2018) Land Cover and Land Use maps of Collection 2 generated under the MapBiomas Amazonia initiative, led by RAISG; data available for download at https://amazonía.mapbiomas.org/"
7	Hydroelectric Power Plants and Small Hydroelectric Plants	"Empresa Nacional de Electricidad (ENDE), 2018; ANEEL, Sep/2019; Ministerio de Energías y Recursos no Renovables del Ecuador, 2019; Organismo Supervisor de la Inversión en Energía y Minería - OSINERGMIN, 2018; Camacho Gabriel and Carrillo Augusto, 2000. EDELCA, 2004. Herrera Karina, 2007. Ministerio del Poder Popular para la Energía Eléctrica, 2013. Grupo Orinoco Energía y Ambiente, 2015."
8	Oil Fields	"Viceministerio de Exploración y Explotación de Hidrocarburos (VMEEH), 2017; ANP - Banco de Dados de Exploração e Produção BDEP, 2019; Mapa digital de Áreas. Agencia Nacional de Hidrocarburos, 2019; Ministerio de Energías y Recursos no Renovables del Ecuador, 2019; PerúPetro/ Ministerio de Energía y Minas - MINEM, 2019; Ministerio de Energía y Petróleo, 2017."

Source: RAISG

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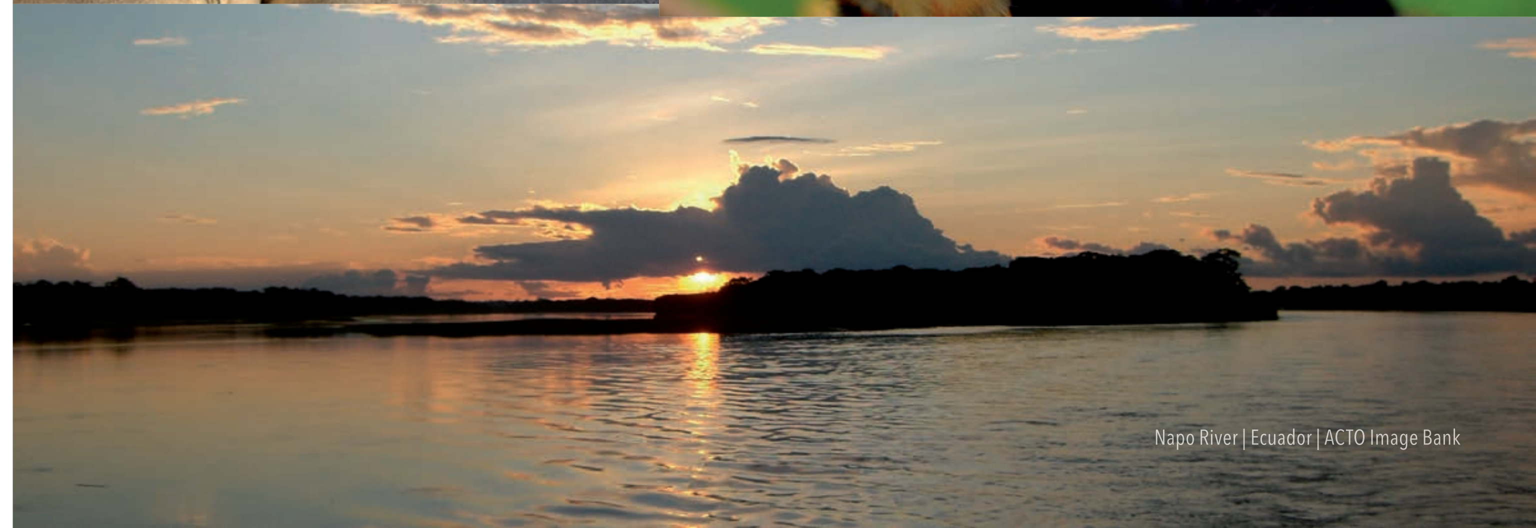
City of Manaus | Brazil | ACTO Image Bank

Market in Belém | Pará - Brazil (2010)
Rui Faquini / ANA Image Bank


Toucan | ACTO Image Bank


Napo River | Ecuador | ACTO Image Bank


AMAZON PROJECT
REGIONAL ACTION IN THE AREA OF WATER RESOURCES
ANA
NATIONAL WATER AND SANITATION AGENCY - BRAZIL
ACTO
Amazon Cooperation Treaty Organization
ABC
BRAZILIAN COOPERATION AGENCY
MINISTRY OF FOREIGN AFFAIRS
MINISTRY OF FOREIGN AFFAIRS
FEDERATIVE REPUBLIC OF BRAZIL
cobrape