v. 3, n. 16, 2023

Journal of
Engineering
Research

AN ANALYSIS OF THE DISTRIBUTION AND SPATIALITY OF OFFICIAL RAINFALL STATIONS IN BRAZIL. EMPHASIS ON THE AMAZON HYDROGRAPHIC REGION

Dênis Aguero do Nascimento
National Institute of Amazonian Research -Master in Management and Regulation of Water Resources

Alderlene Pimentel de Brito
National Institute of Amazonian Research -PhD in Climate and Environment

Joecila Santos da Silva
State University of Amazonas -Professor / Researcher

Carlossandro Carvalho de Albuquerque
State University of Amazonas -Professor / Researcher

Journal of Engineering Research ISSN 2764-1317
DOI 10.22533/at.ed.3173162311054

Abstract: Due to the importance of the Amazon as an environmental entity, whose hydrodynamics are essential in its natural systems, and considering that rainfall monitoring is essential to better understand these phenomena, this work aimed at synthesizing knowledge about the numbers of water resources of the Amazon through a bibliographic review, and ascertained the number, spatiality, and history of official rainfall stations in the Amazon Hydrographic Brazilian Region (RHAMZ). We bring to light information obtained from the metadata analysis of the number of official stations between the years 1910 and 2019, obtained from the National System of Information on Water Resources (SNIRH). The RHAMZ is the largest Hydrographic Region in Brazil, corresponding to about 62.5% of the area of the Amazon basin and 45.4% of the national territory, where approximately 82% of the waters of the Brazilian hydrography flow. Some of our findings indicate that only 6.22% of the 12,518 official rainfall stations are in the RHAMZ. And that 93.5% are under 40 years old. There has been significant progress in the historical implementation of rainfall stations since the 2000s. However, in the scope of achieving excellence in the quantity and distribution of these stations, scientific research is faced with logistical and infrastructure problems.
Keywords – Pluviometry; Brazilian Hydrometeorological Network; Amazon Hydrographic Region

INTRODUCTION

THE HYDROGRAPHIC REGIONS

Due to the intrinsic nature of water resources in the formation of Earth's landscapes and maintenance of all forms of life, Brazil developed the National Water Resources Policy (PNRH), established by Law 9.433 (1997). This legal component establishes fundamental principles for the social and environmental management of this natural resource. Among them, the definition of the hydrographic basin as a reference spatial unit for water control and monitoring (BRASIL, 1997).

The National Water Resources Council (CNRH) is responsible for the PNRH. To optimize water management in Brazil, the CNRH redefined the protocols for mapping and classifying the hydrography and watersheds of the South American continent. The method adopted is that of Otto Pfafstetter, initially on a base scale of 1:1,000,000. The objective was to establish a reference methodology that would allow the adoption of standardized procedures for the hydrogeopolitical grouping of basins and regional subdivisions of the continent's hydrography (BRASIL, 2003). The continental definition was given by the territorial meaning of the geopolitical limits of the countries in the spatiality of the great hydrographic basins. Information on the Otto's method can be found in Soares and Galvão (2005).

The result was a better characterization of the interfluves of the large hydrographic basins, providing more accurate geospatial data. From this, having the spatial unit of the basins as a geographical basis, data was formed to define the Hydrographic Regions (RH). In the first level, from the South American continent. On a second level, on a larger scale, from Brazil (BRASIL, 2003). See Figure 1 and Table 1 for map and identification of HRs.

The Brazilian hydrography resulted in 12 RHs. For their spatial definition, in addition to the observations in the previous paragraph, natural, social, and economic characteristics were considered. These are formed by large basins, a group of basins or nearby hydrographic sub-basins (BRASIL, 2003). The description of the HRs is presented in Table 2.

The National Water and Basic Sanitation

Agency (ANA) is the federal agency responsible for implementing the PNRH. For monitoring and recording information, ANA has developed partnerships with public and private entities. These form the National Hydrometeorological Network (RHN). The data generation framework is composed of approximately 23,000 hydrometeorological stations distributed throughout the national territory of Brazil. Of these stations, 4,807 represent the National Basic Network (RBN), managed exclusively by ANA. Of which, 2,808 are rainfall stations and 1,999 are fluviometric stations (ANA, 2021).

The data generated by RHN are inserted in the National System of Information on Water Resources (SNIRH), complying with one of the recommendations of the Water Law. It is a system for recording, collecting, editing, storing and retrieving hydrological data, as well as intervening factors for management. (ANA, 2021).

THE IMPORTANCE AND CHALLENGES OF HYDROMETEOROLOGICAL MONITORING

Understanding the dynamics and interrelationship of water with the environment in which it occurs is the main impetus for managing this finite natural resource. Due to this, the 8th article of the PNRH establishes that the Water Resources Plans must be prepared from the hydrographic basin (BRAZIL, 1997). This based on the geoclimatic characteristics of a region formed by one or more river basins that the quantity and strategic location of hydrometeorological monitoring stations is determined. (WMO, 2008). The variables to consider are many, and their occurrences are random. Notwithstanding this, infrastructure factors imply an increase in challenges for assertiveness in technical decisions regarding the installation and maintenance of monitoring stations.

In a system for generating and monitoring hydroclimatic data, not only the extent of its geographic representativeness is weighed, but also the longevity and certification of its records. Ishihara *et al.*, (2014) *highlighted these observations when considering how they relate to the consistency of rainfall data in the Brazilian Amazon. According to the authors, there are few long-term monitoring series, most of which are less than 50 years. In addition, they observed temporal flaws in the continuity of records. They also concluded that the distribution unevenness of the stations is a negative point in the spatial standardization of rainfall monitoring.*

Vespuci *et al.*, (2016) evaluated, using the reliability index method, the quality of data from the historical series of the level/flow parameters of the 413 fluviometric stations in the state of Goiás. They concluded, as did Ishihara et al. (2014), that the discontinuity of the series and their time gaps are the main obstacles to their adoption in advanced projects.

Mathematical models are the main tools for filling gaps in historical series. Rainfall is the main variable for determining or estimating the flow of water networks with few or no monitored records. This variable stands out for being the main agent in the occurrence of the hydrological cycle in continental areas (HORNBERGER, WIBERG, *et al.*, 2014).

The occurrence of rainfall is mostly the result of moisture transported to the continents by atmospheric currents that capture the evaporation from the oceans. The interaction of this humidity with varied temperatures of the terrestrial surface promotes the occurrence of complex physical processes in the atmosphere that form rain clouds and the subsequent rainfall. (BORMA, 2013). This phenomenon intensifies as part of the precipitation returns to the atmosphere in

Figure 1. Macro scale of the Hydrographic Regions and Hydrographic Basins of South America

Source: Adapted from Ministry of Environment and Climate Change _(BRASIL, 2003)

Code	Denomination
0	Titicaca hydrographic region
1	Pacific coastal hydrographic region
2	Orinoco watershed
3	North Atlantic coastal hydrographic region
4	Amazon watershed
5	Marajó hydrographic region
6	Tocantins watershed
7	South Atlantic coastal hydrographic region
8	Paraná watershed
9	Pampas hydrographic region

Table 1. Codification and naming of the South American Hydrographic Regions

Source: Adapted from Ministry of Environment and Climate Change (BRASIL, 2003)

Journal of Engineering Research ISSN 2764-1317 DOI 10.22533/at.ed.3173162311054

Hydrographic Region	Formation
Amazonian	The largest of the RHs is constituted by the Brazilian portion of the Amazon Basin, as well as river basins on the Island of Marajó and river basins in the State of Amapá that flow into the North Atlantic, which covers territories of the following states: Acre, Amazonas, Rondônia, Roraima, Amapá, Pará and Mato Grosso.
Tocantins /Araguaia	Comprised of the basin of the Tocantins River to its mouth in the Atlantic Ocean and covers territories of the following states: Goiás, Tocantins, Pará, Maranhão, Mato Grosso and the Federal District.
West northeast Atlantic	Consists of the basins of rivers that flow into the Atlantic - northeast stretch. It covers territories of the following states: Maranhão and a small portion of Pará
Parnaíba	It is constituted by the Parnaíba river basin, which covers territories of the following states: Ceará, Piauí and Maranhão.
East northeast Atlantic	Consists of the basins of the rivers that flow into the Atlantic - Northeast stretch and covers territories of the following states: Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco and Alagoas
São Francisco	Constituted by the São Francisco River basin and covers territories of the following states: Bahia, Minas Gerais, Pernambuco, Alagoas, Sergipe, Goiás and the Federal District
East Atlantic	Consists of the river basins that flow into the Atlantic - east section and covers territories of the following states: Minas Gerais, Espírito Santo, Rio de Janeiro, São Paulo and Paraná
Southeast Atlantic	Consists of river basins that flow into the Atlantic - Southeast section and covers territories of the following states: Minas Gerais, Espírito Santo, Rio de Janeiro, São Paulo and Paraná.
Paraná	Constituted by the basin of the Paraná River located in the national territory and covers territories of the following states: São Paulo, Paraná, Mato Grosso do Sul, Minas Gerais, Goiás, Santa Catarina and the Federal District
Uruguay	Constituted by the basin of the Uruguay River located in the national territory and covers territories of the following states: Rio Grande do Sul and Santa Catarina
South Atlantic	Consists of the basins of the rivers that flow into the Atlantic - southern section, which covers territories of the following states: São Paulo, Paraná, Santa Catarina and Rio Grande do Sul.
Paraguay	Constituted by the basin of the Paraguay River located in the national territory and covers territories of the following states: Mato Grosso and Mato Grosso do Sul

Table 2. The Hydrographic Regions of Brazil and their constitutions

Source: Adapted from Ministry of Environment and Climate Change (BRASIL, 2003)

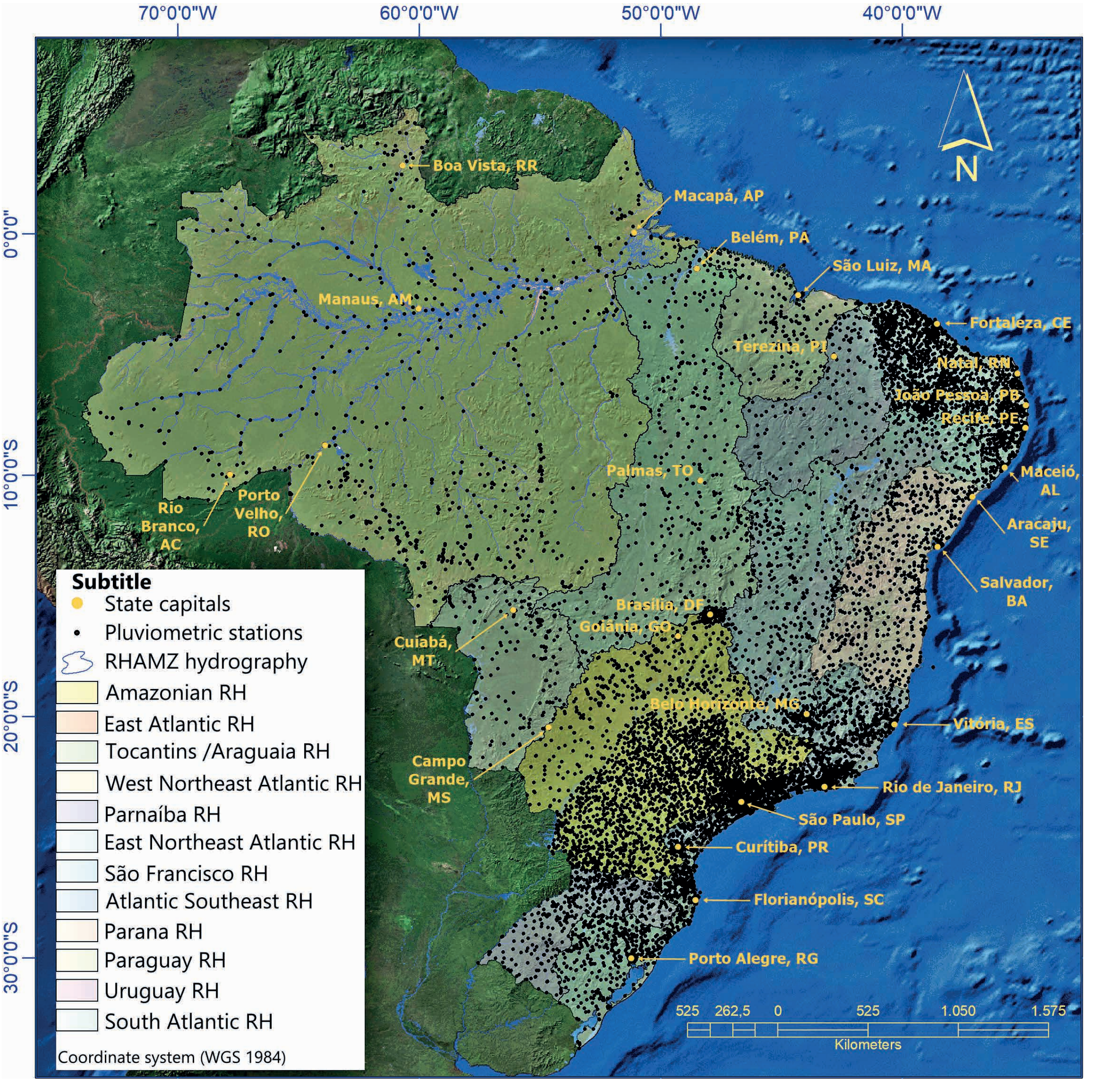

Figure 2. Hydrographic Regions and rainfall stations of the National Hydrometeorological Network

Source: Generated from SNIRH metadata_(ANA, 2021) the form of evapotranspiration, establishing hydrological recycling as varied as the biophysical characteristics of the surface, both for micro, meso and macro scales. (NGEE-TROPICS, 2021); (TOMASELLA, HODNETT, *et al.*, 2007).

THE MAGNITUDE OF AMAZONIAN HYDRODYNAMICS

The Amazon basin is formed by the most extensive hydrographic network on Earth. The annual precipitation varies between 12,000 and 16,000 km³ in a surface area of approximately 6.2 million km² (PNUMA E OTCA, 2008); (MARENGO, 2006). The Amazon Hydrographic Region (RHAMZ) corresponds to about 62.5% of the area of the Amazon basin. This estimated to be approximately 82% of the waters of the national hydrograph flow. It is a percentage that is evident in the magnitude of the average flow of 220,000 m³/s from the Amazon River into the Atlantic Ocean. At, peaks, this volume reaches the mark of 300.000 m³/s (PNUMA E OTCA, 2008).

The magnitudes of hydrological quantities in the Amazon basin do not stand out only in the dynamics of its surface waters. Abreu *et al.*, (2013) studied the geometric characterization of permo-porous units within the scope of sedimentary basins in the region of the state of Acre and under the Solimões, Amazonas and Marajó rivers, which together cover a surface of approximately 1.3 million km². Focusing on the volumetric composition of underground aquifers, it estimated a preliminary volume of 162,520 km³ of water distributed in different scenarios and depths. It is the largest groundwater reserve in the world.

In a literature review on the Amazonian climate, Fisch *et al.,* (1998) concluded that instability currents originating on the north and northeast Atlantic coast would be the main means for the entry of moisture into the Amazon. Diurnal convection, resulting from surface heating and favorable large-scale conditions, promote rapid exchange between water, forest, and atmosphere, this being one of the atmospheric mechanisms that increases rainfall. Also, according to the authors, the convective accumulations of meso and large spatial scales combine with the penetration of frontal systems in the south and southeast regions of Brazil, also constituting a mechanism for generating rainfall. This complex atmospheric system makes the Amazon one of the most irrigated regions in the world.

There are several rainfall regimes in the RHAMZ. The definitions are related to surface characteristics and micro and meso scale atmospheric systems. The levels vary between 1,700 mm, further south of the basin, and 4,000 mm, north and east of the basin. According to Molion (2017), the occurrence of these rains is significantly subjected to the advent of the phenomenon *El Niño* - Southern Oscillation (ENOS). Nascimento *et al.,* (2019) who studied the occurrence of rainfall in the year 2015 from a pluviometric station in the Central Amazon verified a reduction of 80%, in relation to the ten-year historical average, of the precipitated height for the months of November and December, when the ENSO phenomenon began in that year.

Seeking to understand the relationship between the entry and exit of water via the atmosphere of the Amazon, Nobre (2014) studied the emission of moisture from the forest in relation to the precipitation that falls on it. He concluded that the Amazon region evaporates an approximate volume of 20 billion m³ of water daily into the atmosphere. Evapotranspiration influences rainfall through atmospheric recycling processes, also intervening in regional patterns of temperature, air humidity and soil moisture. The water vapor released by the flooded areas, added to the transpiration of the trees, defines the Amazon as the largest convection region on the planet (SILVA, 2010). This exchange of energy between the biosphere and the atmosphere is quite intense. Changes resulting from human intervention in ecosystems can impact atmospheric circulation, moisture transport and consequently the hydrological cycle. Which would cause changes in surface hydrodynamics and, inevitably, in water stocks, altering the water balance at micro and macro scales (TOMASELLA, HODNETT, *et al.*, 2007).

River waters, associated with terrestrial environments, play an important role in the hydrological cycle. They are active in the formation of landscapes because they are connected to the systems of the catchment area, which is directly associated with the dynamics of surface water circulation and evapotranspiration. These and other phenomena establish the hydrological cycle in the different regions of the Amazon basin, influenced by its variables. (BORMA, 2013); (FISCH, MARENGO and NOBRE, 1998); (SILVA, 2010); (TOMASELLA, HODNETT, *et al.*, 2007).

The spatial variability of the Amazon, added to the intraseasonal and interannual effects of the rains that occur in it, significantly influence the hydrological components of the entire system. The understanding of this variability is aggravated by the lack of detailed hydroclimatic data, monitored in smaller spatial scales. They create uncertainties regarding the representativeness of the estimated rainfall regimes. As well as the closure of the water balance (TOMASELLA, HODNETT, *et al.*, 2007); (ISHIHARA, FERNANDES, *et al.*, 2014).

Due to the importance of the Amazon as an environmental entity, whose hydrodynamics are manifested in its natural systems, and considering that rainfall monitoring is essential to better understand these phenomena, the aim of this work was to synthesize knowledge about the numbers of water resources in the Amazon, and ascertain the number, spatiality and history of official rainfall stations in the Amazon Hydrographic Region of Brazil.

MATERIAL AND METHODS

The present study began with a literature review referring to authors who study the management of water resources, climate and meteorology in Brazil and the Amazon region, to support the analysis of the collected data.

To analyze the distribution of the RHN rainfall stations, data from the HidroWeb system, SINIRH's online data availability platform, was accessed. The shape file was downloaded from GIS (Geographic Information System) files with a database of the stations of the RHN[1] and the boundaries of the National Hydrographic Regions. To edit this file, ArcGIS 10.5 software was used. In it, the Layer of HRs was individualized, according to their official identifications. Then, using the Clip tool, the Layer of geographic points of the hydrometeorological stations was fractioned from the delimitations of the RHs.

Metadata was edited in Microsoft Excel. The results of interest were: number of rainfall stations per RH; estimation of the number of stations per square kilometer of each RH using the Equation 1, and, specifically for RHAMZ, the participation percentage of ANA's partner agencies in the operation of official pluviometric stations. In addition, to the progression of the number of official stations over the decades of records. RH areas used in this work were obtained from Marcuzzo (2017).

Equation 1:

$$Est = \frac{A}{N}$$

Where: *Est* corresponds to the spatiality of

1 The information on the HidroWeb website attributes the last update of the GIS data to the year 2019

Journal of Engineering Research ISSN 2764-1317 DOI 10.22533/at.ed.3173162311054

rainfall stations; *N* to the number of rainfall stations per RH; *A* the RH area.

RESULTS AND DISCUSSION

The data showed a great dissymmetry in the distribution of rainfall stations in Brazil. The Hydrographic Regions with the highest densities comprise the states of the southeast, northeast (semi-arid) and south geographic regions. Immediately it is apparent that there is a gap in the spatiality of the stations in the midwest region and north region, RHAMZ location. Figure 2 presents the distribution of RHN rainfall stations in the Hydrographic Regions highlighting the RHAMZ hydrography. It should also be noted that the distributive heterogeneity of the pluviometric stations is invariably related to the population occupation of the Brazilian territory, as well as to the problems of each geographic region. The arrangement of the data in Table 3 favors the analysis between the areas of the hydrographic regions, the numbers of rainfall stations by RH and their spatialities.

In the Southeast Atlantic Hydrographic Region, where the spatial index is 114km²/station, there is a population of approximately 90 million people (IBGE, 2013). Its large metropolises require a large supply of water. A historical example of the water vulnerability of this region is the crisis that occurred in 2014. Marengo, *Et al.*, (2015) concluded that an atypical atmospheric block, generated by a persistent high-pressure system, hindered the development of the main rain-causing systems. This effect, added to the high demand for water and its inefficient management, resulted in a serious shortage, mainly in the city of São Paulo.

The northeast Atlantic Hydrographic Region is the second-best instrumented RH. Its spatial coverage index is 153km²/station. It comprises the states of Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco and Alagoas. This is area is also characterized by the challenges of water insufficiency of the semi-arid region. Because of this, its systematic monitoring is essential in the face of the challenges of managing its waters for approximately 31 million inhabitants. Mainly in large centers established in coastal regions, whose underground water reserves are subject to a decrease in quality under the effect of saline intrusion, requiring strict control of water extraction (FERREIRA e HAIE, 2000).

In the south of Brazil, comprising the RHs of Uruguay and the South Atlantic, with respective spatial indexes of 192 km²/station and 387km²/station, intensive monitoring is associated with flood forecasting (TOLEDO and OTAMI, 1996).

RHAMZ is not exposed to the same difficulties as other HRs in Brazil. Its population density is 10 times lower than the national average. Which rules out hydrological impacts of significant social risk. Although the Amazonian rivers are subject to flooding, according to their hydrological regimes, the people are culturally adapted to this natural condition (SOUZA, 2020).

Of the analyzed metadata, 779 official stations were active in RHAMZ until the year 2019. For historical analysis, 50 stations do not have an activation date. Therefore, the following percentages are referenced to the total of 729 pluviometric installations.

The historical increase in official stations at RHAMZ highlights the challenges of monitoring rainfall over the nearly 120 years of records in the Amazon. Until the 1970s there were 47 official rainfall stations in the 3,946,749 km² of the RHAMZ. Of the total stations activated until 2019, around 93.5% are under 40 years old and 65% under 30 years old. 31.1% were installed after 2010. The *World Meteorological Organization* (WMO) recommends a minimum monitoring period of 30 years to characterize the climate of a region (WMO, 2008).

For rational coverage of the number of seasons throughout history, the graph of the Figure 3 presents two analytical variables: The line is the decennial sum of official stations from the 1910s onwards, when the first records were made. The columns represent the addition of seasons by decade up to the year 2019.

The slow pace between 1910 and 1970 may be related to the low occupation of the Amazon, as well as the lack of specialized labor and low social awareness of the importance of climate studies. In anticipation of a behavioral reversal, the largest addition from the 2000s onwards, 319 stations, may be a consequence of debates and studies related to the role of the Amazon in global climate change.

There is a consensus in the scientific community that hydrometeorological phenomena are directly related to geoclimatic variables of the region. This is the premise for the distribution of meteorological stations. However, there is a dissonance for spatial density recommendations in the scientific community. The WMO (2008) proposes numbers based on contemporary knowledge acquired, making recommendations about the importance of improving studies in this regard. Table 4 summarizes these recommendations.

Based on the WMO (2008) proposal in order to have a systematic evaluation of the densities of the rainfall stations in each RH, we would have to make the count based on the physiographic features of their reliefs. This is not the case with the data presented here, since our spatial reference was the HR areas (Table 3). However, in the case of RHAMZ, it is clear on the map (Figure 2) that the physiography does not correspond to the concentration of stations. There are large spatial gaps in forest areas while most of the monitoring points are in metropolitan regions such as Manaus - AM and Boa Vista - RR, or in the south, where Agribusiness is more vigorous. For agriculture, rainfall data is very useful.

Another observation is the geographic sequences of the installations. Where many follow the channels of the main rivers. On riverbanks are found a majority of cities and towns. This would be related to the Amazon logistic reality, where transport is conducted to inland regions is basically via waterways, as well as the spatial occupation of riverbanks.

While the national average density is 1 station per 695 km², in RHAMZ this index is at least 1 station per 5,000 thousand km². For topographical variations within its boundaries, such as the mountainous base of the Andes Cordilleras to the west, or the highlands to the south and north, the recommended density ratio is 1 station per maximum 2,500 km². For the coastal region, to the east, with approximately 750 km of coastline, the density would be 1 station for every 9,000 km².

The northern region is the least populated, but also lacks specialized hydrometeorological institutions. This is a relevant observation considering that 80% of RHN's pluviometric stations are from ANA's partner institutions. At RHAMZ this fact is different, the ANA is responsible for financing 58.3% of the stations. Data maintenance and generation is carried out by 83 partner operators. Most of them are regional public entities. Others are mixed economy. The contracted private companies are from other regions of Brazil. The five main institutions operate in 64.9% of the stations. They are as follows: CPRM[2]

2 Geological Survey of Brazil – Federal State

Hydrographic Regions					Pluviometric stations		
Number	Hydrographic Region	Area (km²)	National hydrography (%)	Accumulated national hydrography (%)	Quantity	RHN Participation (%)	Spatiality (km²/est)
1	Amazonian	3.946.749	45,4	45,4	779	6,22	5.066
2	Tocantins-Araguaia	922.938	10,6	56,0	517	4,13	1.785
3	Paraná	882.579	10,1	66,1	3346	26,73	264
4	São Francisco	659.659	7,6	73,7	1017	8,12	649
5	East Atlantic	408.275	4,7	78,4	792	6,33	515
6	Paraguay	362.957	4,2	82,6	221	1,77	1.642
7	Parnaíba	343.947	4,0	86,5	258	2,06	1.333
8	East NE Atlantic	309.445	3,6	90,1	2021	16,14	153
9	West NE Atlantic	279.609	3,2	93,3	212	1,69	1.319
10	Southeast Atlantic	220.658	2,5	95,8	1931	15,43	114
11	South Atlantic	186.833	2,1	98,0	973	7,77	192
12	Uruguay	174.719	2,0	100,0	451	3,60	387
Total national hydrographic: 8.698.367 km²				Total rainfall stations: 12.518			

Table 3: Number, area, and density of rainfall stations by Hydrographic Region by the year 2019

Source: Data generated from HidroWeb platform records and from Marcuzzo (2017)

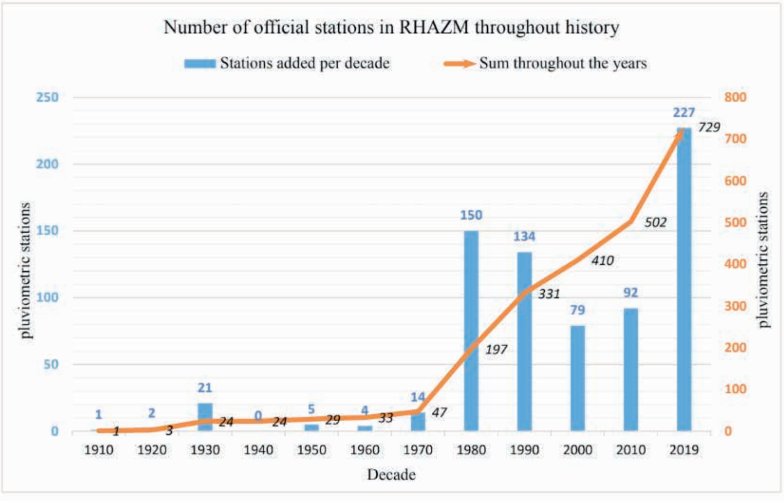

Figure 3. Decennial historic increment of official rainfall stations at RHAMZ

Physiographic Characteristic	Amplitude espacial (km²)	
	Conventional stations	Automatic stations
Coast regions	900	9.000
Mountainous regions	250	2.500
Flat or undulating regions	575	5.750
Slightly mountainous regions	575	5.750
Small islands	25	250
Urban areas	-	20
Arid and polar zones	10.000	100.000

Table 4: Spatial density recommended by the WMO for rainfall stations according to the physiographic characteristics of the Earth's surface.

Source: Adapted from WMO (2008).

(40%); Construfam[3] (7,61%); UFC[4] (6,71%); Cohidro[5] (5,55%); INMET[6] (5,03%).

CONCLUSIONS

This work quantified the number of rainfall stations in the 12 hydrographic regions of Brazil, estimating their spatiality. Emphasis was placed on RHAMZ due to the high volumes of its hydrological components and the important ecosystem services associated with them. It provided an opportunity to debate the technical procedures of national hydrological monitoring, highlighting that the distribution of stations must be determined by criteria that consider the spatial scale of the monitoring area, in addition to temporary meteorological phenomena associated with variations in the physiographic characteristics of the study region.

In the remote areas of the country, characterized by regions with diverse climatic varieties and biodiversity, Brazil has taken on the challenge of monitoring its water resources. However, there are still challenges to achieve excellence, especially in the north of the country where the number and distribution of rainfall stations are insufficient. A wide and uniform network would allow for more representative interpretations of the rainfall regimes and the hydrology of the Amazon basin, of which approximately 62% of the surface is in Brazil.

RHAMZ has the lowest percentage of stations in the National Hydrometeorological Network (6.22%). It contrasts with the percentage of its area in the Brazilian hydrography (45,4%). And mainly, its incomparable water quantities (82% of surface hydrological reserves). Factors related to the large territorial extension, lack of qualified labor and the difficult geographic accessibility are realities that make the hydrological monitoring of this RH difficult. In this sense, it is important to develop initiatives to mitigate these factors.

The importance of the continuous and systematic hydroclimatic monitoring of the RHAMZ is consolidated in the need to improve the knowledge of its hydrological dynamics from the micro and meso geographic scale. Added to other sciences, it fills gaps in the knowledge of the potential of the Amazon as an environmental entity at all geographic scales. An inherent fact, also, the management of water resources, where due to its natural characteristics, must be fundamentally based on the quantitative knowledge of this natural resource, which, although abundant in this RHAMZ, proves to be susceptible to climate variations and surface cover transformations.

3 Construfam Engenharia e Empreendimentos LTDA –private company

4 UFC Engenharia`` – Private company

5 Company for the development of water resources and irrigation of Sergipe – Mixed economy

6 National Institute of Meteorology - Federal State

REFERENCES

ABREU, F. D. A. M. D.; CAVALCANTE, I. N.; MATTA, M. A. D. S. O Sistema Aqüífero Grande Amazônia – Saga: Um Imenso Potencial de Água Subterrânea no Braisil. **Anais do III Congresso Internacional de Meio Ambiente Subterrâneo**, 10 fevereiro 2013.

ANA. Sistema Nacional de Informações de Recursos Hídricos. **HidroWeb**, 2021. Disponivel em: <https://www.snirh.gov.br/hidroweb/apresentacao>. Acesso em: 2 maio 2021.

BORMA, L. D. S. Mudanças climáticas e o ciclo hidrológico no Brazil. In: BRUM, A. L., et al. **Sustentabilidade do uso da água nos trópicos e sub-trópicos**. 1. ed. Ijuí: Unijuí, v. 1, 2013. p. 63-102.

BRAZIL. LEI 9.433 - Politica Nacional de Recursos Hídricos. **Planalto - Presidência da República**, 8 janeiro 1997. Disponivel em: <http://www.planalto.gov.br/ccivil_03/leis/l9433.htm>. Acesso em: 12 abril 2023.

BRAZIL. RESOLUÇÃO N° 32 - Define metodologia de codificação e procedimentos de subdivisões em agrupamentos de bacias e regiões hidrográficas do Brazil. **Ministério do Meio Ambiente e Mudança do Clima**, 17 dezembro 2003. Disponivel em: <https://www.ceivap.org.br/ligislacao/Resolucoes-CNRH/Resolucao-CNRH%2030.pdf>. Acesso em: 21 abril 2023.

FERREIRA, J. F. D. S.; HAIE, N. Planejamento e gestão global de recursos hídricos costeiros: Estratégias para a prevenção e controlo da intrusão salina. **5º Congresso Nacional da Água** -, Lisboa, 2000.

FISCH, G.; MARENGO, J. A.; NOBRE, C. A. Uma revisao geral do clima da Amazônia. **Acta Amazonica**, Manaus - AM, v. 28, n. 2, p. 101 - 126, 1998.

HORNBERGER, G. M. et al. **Elements of Physical Hydrology**. 2°. ed. Baltimore: John Hopkins University Press, 2014.

IBGE. **Atlas do Censo Demográfico 2010**. Instituto Brazileiro de Geografi a e Estatística. Rio de Janeiro - RJ, p. 160. 2013.

ISHIHARA, J. H. et al. AVALIAÇÃO DO MONITORAMENTO PLUVIOMÉTRICO DA AMAZÔNIA LEGAL. **Engenharia Ambiental; Recursos Hídricos; Precipitação**, Espírito Santo do Pinhal, v. 10, n. 3, p. 132-144, 28 abr. 2014.

MARCUZZO, F. F. N. Bacias hidrográficas e regiões hidrográficas do Brazil: cálculo de áreas, diferenças e considerações. **XXII Simpósio Brazileiro de Recursos Hídricos**, Florianópolis, 26 Novembro 2017. Disponivel em: <http://rigeo.cprm.gov.br/jspui/handle/doc/18492>. Acesso em: 14 abril 2021.

MARENGO, J. A. On the Hydrological Cycle of the Amazon Basin: A historical review and current. Revista Brazileira de Meteorologia. **Revista Brazileira de Meteorologia**, São José dos Campos - SP, v. 21, n. 3, p. 1 - 19, 2006.

MARENGO, J. et al. A seca e a crise hídrica de 2014-2015 de São Paulo. **Revista USP**, São Paulo, julho/agosto/setembro 2015. 13.

MOLION, L. C. B. Gênese do El Niño. **Revista Brazileira de Climatologia**, Curitiba - PR, v. 21, n. eletrônica, p. 1 - 4, julio - dezembro 2017.

NASCIMENTO, D. A. et al. A análise pluviométrica na gestão dos recursos hídricos: Exame de dados de 2015 de uma estação pluviométrica da Amazônia Central. In: POISSON, E. **Recursos Hídricos em Foco - Volume 1**. 1. ed. Belo Horizonte - MG: Poisson, v. 1, 2019. Cap. 16, p. 116 - 125.

NGEE-TROPICS. Next-Generation Ecosystem Experiments – Tropics. **NGEE-Tropics**, 2021. Disponivel em: <https://ngee-tropics.lbl.gov/>. Acesso em: 19 abril 2021.

NOBRE, A. D. **O Futuro Climático da Amazônia - Relatório de Avaliação científica**. Articulación Regional Amazónica - ARA. São Paulo - SP, p. 6 - 42. 2014.

PNUMA E OTCA. **GEOAMAZÔNIA. Perspectivas do meio ambiente na Amazônia**. Brasília: PNUMA, 2008.

SILVA, J. S. D. **Altimetria Espacial Aplicada aos Processos Hídricos em Zonas Úmidas da Bacia Amazonian**. Tese de doutorado - Programa de Engenharia Civil da UFRJ / COPPE. Rio de Janeiro - RJ, p. 244. 2010.

SOARES, G.; MENESES, P. R. Avaliação dos sistemas de classificação e codificação das bacias hidrográficas Brazileiras. **Anais XII Simpósio Brazileiro de Sensoriamento Remoto - SBSR**, Goiania/GO, Abril 2005. 7.

SOUZA, J. D. O. O ciclo hidrológico na percepção de quem vive e mora na floresta Amazonian. In: ORGANIZADORES: HIGUCHI, M. I. G.; LACERDA JUNIOR, J. C. **Relações Pessoa-Ambiente Amazônico**. Rio de Janeiro: Autografia Edição e Comunicação LTDA, 2020. p. 108-128.

TOLEDO, Y. I. M. D.; OTAMI, M. N. PROJETOS DE MANEJO DE MICROBACIAS HIDROGRÁFICAS NO BRAZIL. **Informações Economicas**, São Paulo, v. 26, n. 11, p. 47 - 51, 01 novembro 1996.

TOMASELLA, J. et al. The water balance of an Amazônian micro- catchment: the effect of interannual variability of rainfall on hydrological behaviour. **Hydrological Processes**, v. 22, n. 13, p. 2133-2147, 30 Outubro 2007. ISSN 0885-6087.

VESPUCCI, ARIEL GODINHO; DOS SANTOS, JÚNIO GREGÓRIO ROZA; BAYER, MAXIMILIANO. Estações fluviométricas do estado de Goiás: qualificação dos dados hidrológicos disponíveis na base HIDROWEB/ANA. **Ateliê Geográfico**, Goiania, v. 10, n. 3, p. 89- 108, dezembro 2016.

WMO. **Guide to Hydrological Practices N° 168 - Hydrology – From Measurement to Hydrological Information**. Sixth edition. ed. Geneva: Chairperson, Publications Board, v. 1, 2008.