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Application Of The Hierarchical Process Analysis Technique To The Development Of Methodology For Mapping The Distribution Of Altitudinal Rain Forests In The Brazilian Semiarid

Aplicação da técnica de análise dos processos hierarquicos ao desenvolvimento de metodologia para o mapeamento da distribuição de brejos de altitude no semiárido brasileiro

Renilson Pinto da Silva Ramos[I], Bartolomeu Israel de Souza [II], Daisy Beserra Lucena [III]

ABSTRACT

Altitudinal Wetland Forests are fields with humid and subhumid climates located in the interior of the Brazilian semiarid that are linked to the climate past of this region. This dry climate domain region has high importance due to both the presence of paleoclimate remnants and its developed economy. The purpose of this work was to try to indicate through mapping, beyond what is officially known, new areas that may include Altitudinal Wetland Forests. The methodology developed was based on data manipulation in a GIS environment applying analysis of hierarchical processes using the altitude variables, rainfall, and vegetation in the distribution of Altitudinal Wetland Forests throughout the Brazilian semiarid. It was possible to indicate new areas with high and low probabilities of the occurrence of Altitudinal Wetland Forests, beyond those without any probability. The obtained results indicate that investigations should be carried out to confirm the results of this study and to provide information for interventions in these areas, both from the environmental point of view and for its sustainable agricultural use.

Keywords: Damp saws; Wet Mountains; Hierarchical Process Analysis.

RESUMO

Os "Brejos de Altitude" são áreas de clima úmido e subúmido localizados no interior do Semiárido Brasileiro que estão ligadas ao passado climático dessa região. Possuem elevada importância, tanto como remanescentes paleoclimáticos, como pela economia desenvolvida em uma região de domínio de clima seco. O propósito desse trabalho foi indicar através de um mapeamento, para além do que se conhece oficialmente, novas áreas com a possibilidade de existência de Brejos de Altitude. A metodologia desenvolvida foi baseada na manipulação de dados em ambiente SIG para a aplicação da Análise dos Processos Hierárquicos, utilizando

[I] Mestrando pelo programa de Pós-Graduação em Geografia da Universidade Federal da Paraíba. E-mail renilsonr5@hotmail.com . ORCID: https://orcid.org/0000-0003-3209-514X

[II] Professor associado da Universidade Federal da Paraíba, estando lotado no Departamento de Geociências. Leciona nos cursos de graduação em Geografia, Biologia e Engenharia Ambiental e na pós-graduação (mestrado e doutorado) em Geografia e Programa Regional. E-mail bartolomeuisrael@gmail.com. ORCID https://orcid.org/0000-0003-2173-8314

[III] Professora associada do Departamento de Geociências (DGEOC) da Universidade Federal da Paraíba (UFPB) Campus I, João Pessoa, e professora credenciada no Programa de Pós-Graduação em Geografia pela Universidade Federal da Paraíba. Vice líder do Grupo de Estudo e Pesquisa em Geografia Física e Dinâmicas Socioambientais (GEOFISA) na Universidade Federal da Paraíba. E-mail Daisylucena@yahoo.com . ORCID https://orcid.org/0000-0002-1645-9743

as variáveis altitude, pluviosidade e vegetação, em sua distribuição por todo o Semiárido Brasileiro. Foi possível indicar novas áreas com alta e baixa probabilidade da ocorrência de Brejos de Altitude, além daquelas sem probabilidade. Os resultados obtidos apontam para que investigações sejam efetuadas no sentido de confirmar o que foi indicado pelas técnicas utilizadas nesse trabalho, subsidiando assim informações que busquem a intervenção nessas áreas, tanto do ponto de vista ambiental como para o seu uso agropecuário sustentável.

Palavras-chave: Serras úmidas; Matas úmidas; Análise dos Processos Hierárquicos.

1 INTRODUCTION

According to Ab'Sáber (1974), there are 3 three semiarid regions in South America: the southern cone of the continent, the dominance of caatingas in the Brazilian semiarid, and the semiarid Guajira of Venezuela. In describing the Brazilian semiarid, the author refers to it as:

> [...] an interspace of at least three thousand kilometers of this southern desert strip, there is a compact semiarid region, with great spatial continuity and indelible morphoclimatic family air, in the interplanaltic, hot and dry depressions of Northeast Brazil, which is also the Northeast of the South American continent itself (AB'SABER, 1974, p. 02, our translation).

Inside of areas that comprises the Brazilian semiarid there are specific spot of higher humidity that are known as altitudinal rain forests. Understanding the dynamics of these humid interior areas can lead to a better understanding of the paleoclimatic characteristics of the Brazilian semiarid region. The most accepted hypothesis about the formation of these Atlantic Forest enclaves is that in the Pleistocene, climatic changes resulted in the advance of the tropical forest to the interior of the continent, establishing connections between the Amazon and the Atlantic Forest. After this period, the forest vegetation retreated to what is currently seen to be dominant, except for the locations that managed to preserve the old humidity pattern, which is mainly dominant in windward mountains and valleys with permanent sources of water (AB'SABER, 1985; PENNINGTON, PRADO and PENDRY, 2000; TABARELLI and SANTOS, 2004; SANTOS *et al.,* 2007; NEVES *et al.,* 2015; BASTOS *et al.,* 2016; THOMÉ *et al.,* 2016; LEDO and COLLI, 2017; LAVOR *et al.* , 2018).

Despite the previous consideration, Ab'Saber (1985) defined the typology of Wetland Forests into more categories, which he classified according to their geological, geomorphological and climatological characteristics: Summit Wetland Forests or Altitudinal

Wetland Forests, in the locations that are windward of humid masses, where orographic rains occur; Hillside Wetland Forests, which undergo processes similar to the summit Wetland Forests and are also in windward areas; Wet Valleys Forests, which formed in shallow areas in alluvial pockets as well as in areas of inflow of marine air; and Source Wetland Forest, where there is some accumulation of water, with springs or permanent sources.

Wetland Forests are historically configured as areas that are sought for the development of more intense agricultural activity due to their peculiar characteristics concerning the semiarid region. Such spot is dominated by banana, coffee, cassava, corn, beans, among others, and generally, serves as refuges for some plant populations in the driest areas in periods of prolonged drought (AB'SABER, 1985; TABARELLI and SANTOS, 2004; SOUZA and OLIVEIRA, 2006).

According to Silva Junior *et al.,* (2020) in a period from 1985 to 2018 12% of the forests in Brazil were deforested, causing huge losses to biodiversity, reducing the capacity for improving of the hydrological cycle, influencing climate changes, and causing negative impacts on society. Given the above information, Wetland Forests are undergoing a strong degradation process. Much of the area's native vegetation, approximately 49%, has become extinct over the years, and one of the main reasons for this mass extinction is the impacts on seed-dispersing fauna, whether due to hunting or the elimination of forest cover, which indicated that greater protection and more sustainable use of these areas are required (TABARELLI and SANTOS, 2004; SOUZA and OLIVEIRA, 2006; CARVALHO, 2011). Still, in this context, the conservation of these areas is essential, taking into account their role as havens in a predominantly semiarid region, where the intensification of land use has had negative effects on species richness and ecosystem processes (HOOPER *et al.,* 2012; MANHÃES *et al.,* 2016).

In addition to the problems mentioned above, there is also a lack of updated information on the location of these altitudinal rain forests in the semiarid region. Some studies have attempted to define areas where these wet enclaves are likely to occur, as in the case of Tabarelli and Santos (2004); Souza and Oliveira (2006); Rodrigues *et al.,* (2008); Brandão *et al.,* (2016); GOIS *et al.,* 2019; however, there are likely places with altitudinal rain forests that have not yet been identified, some projects have mapped the land surface in

Brazil, such as mapbiomas, but have not included the altitudinal rain forests in their research, thus is a need for studies performing in this location.

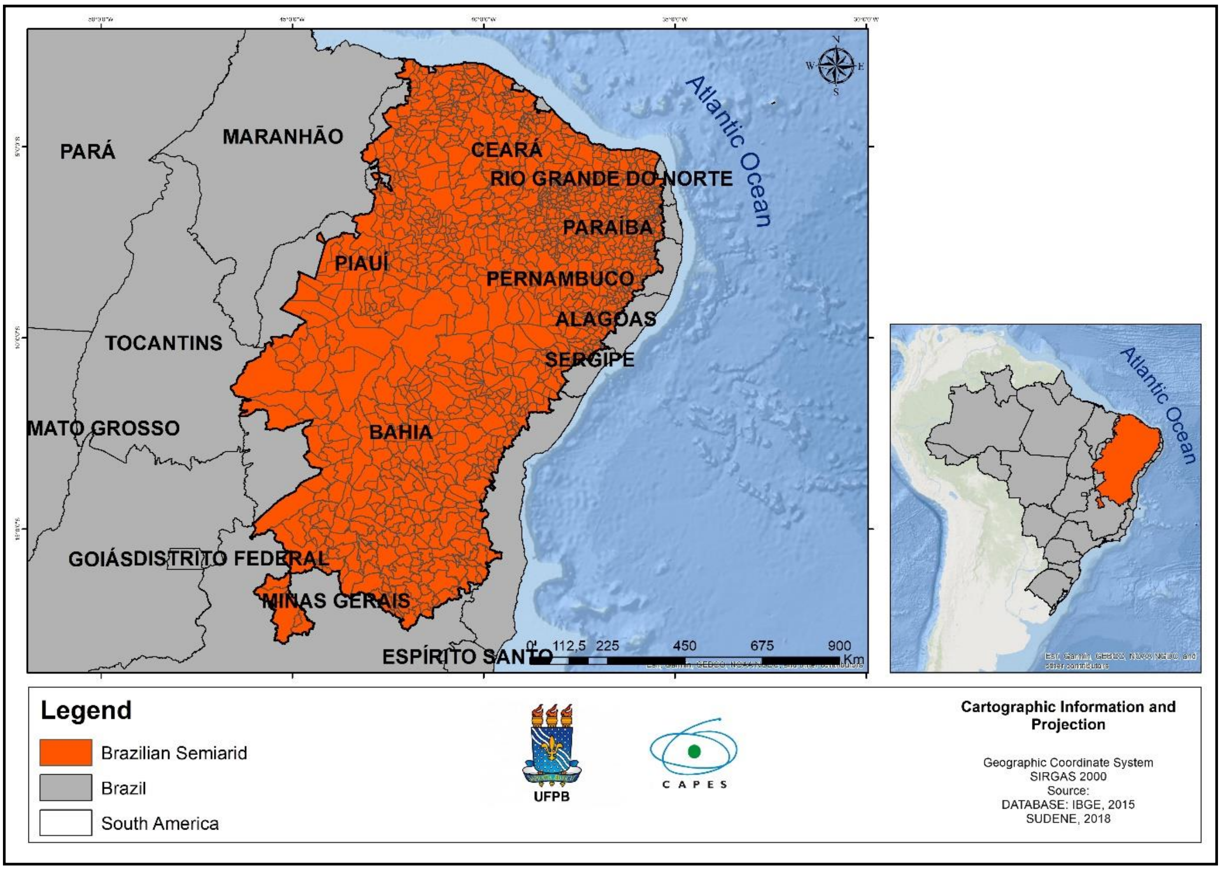
Thus, the objective of the present work is to identify areas in the Brazilian semiarid region where altitudinal wetland forests are likely to occur and map them. The aim of this was to contribute to the creation of basic information about the spot of the altitudinal rain forests, fundamental for the development of public policies, monitoring, and studies focused on the environment in these spaces.

2 MATERIALS AND METHODS

2.1 The location of the study area

The Brazilian semiarid is an area defined by the 1989 federal law No. 7,867 is currently composed of 1262 municipalities located between longitude 35º5'00 '' and 46º5'00 '' W and between latitudes 2º0'00 '' and 18º0 ' 00 '' S, as seen in Figure 1 (SUDENE, 2018, p. 01).

Figure 1 - Location Map of the Brazilian Semiarid



Prepared by the authors (2020) based on data from IBGE (2015) and SUDENE (2011).

These damply areas, due to their particular characteristics, have implications through dynamics of their environmental system and are regionally called Altitudinal Wetland Forests. These places were connected to the Amazon and the Atlantic Forest in a past period of greater rainfall (MEDEIROS, 2016; SOBRAL-SOUZA, LIMA-RIBEIRO, and SOLFERINI, 2015) and retracted during the Last Glacial Maximum, creating ecological refuges for a series of species that are surrounded by semiarid habitats (WERNECK *et al.,* 2011; PRANCE, 1982). In this way, Wetland Forests always appear to be in disagreement with the characteristics of the surrounding areas, with rain, soil, and drainage systems that most correspond to an area of tropical forest, even though they are in the middle of the Caatinga. Because they are residue of Wetland Forests, these areas have rich biodiversity, with different types of species adapted to the conditions of these areas, which serve as refuges for many species of plants (AB'SABER, 1985; TABARELLI and SANTOS, 2004; SOUZA and OLIVEIRA , 2006; LIMA *et al.,* 2015; SAITER *et al.,* 2016; LOPES, RAMOS and ALMEIDA, 20017 MEDEIROS and CESTARO, 2019).

Initially, all areas 500–1100 meters above sea level, in which alluvial rivers existed, were considered to be Wetland Forests. Therefore, all the areas that were located at that specific height, that had an area of sediment accumulation, and that periodically suffered from floods were considered to be Wetland Forests. Subsequently, any area that had deep soils, high rainfall, and a hot and humid climate was also treated as a Wetland Forest. As one of their main characteristics, rainfall in these areas tends to average between 900 and 1300 mm per year (AB'SABER, 1985; LOCATELLI and MACHADO, 2004; TABARELLI and SANTOS, 2004).

2.2 Acquisition of orbital images and cartographic data

The delimitation used for the Brazilian semiarid region was elaborated by the Laboratory of Analysis and Processing of Satellite Images (LAPIS), which was approved by the Northeast Development Superintendence (SUDENE). In this context, for the mapping of altitudinal wetland forests, three variables were used, namely, altimetry, vegetation, and rainfall, of which only altimetry can be classified as primary data in this research. These data were collected from the TOPODATA project, which available at the site: https://www.webmapit.com.br/inpe/topodata/, and were used in Digital Elevation Models (MDE) of the Shuttle Radar Topography Mission at a spatial resolution of 30 meters. A total of 96 sheets were worked on during the development of this study.

Secondary data on vegetation were obtained from the website of the Brazilian Institute of Geography and Statistics – IBGE (https://www.ibge.gov.br/geociencias/informacoesambientais/vegetacao.html) at a scale of 1: 250,000, while data with total rainfall values were obtained from the website of the National Institute for Space Research - INPE (http://www.dpi.inpe.br/Ambdata/download.php); however, these products were from the worldclim project (FICK and HIJMANS, 2017), which provides information about global climate patterns generated from the relationship between the MODIS sensor response with surface temperatures, cloud cover, latitude, and longitude, as well as the location's altimetry.

2.3 Software, digital image processing, and organization of the GIS environment

Two programs were used, ArcGIS 10.5 from ESRI, with a free trial license, and the free GIS QGIS 2.4. To better organize the execution time of the works carried out during this research, as well as to better archive the data for later work, the creation of a database to provide the formulation of a Geographic Information System - GIS), which is, the turn was divided into sections for matrix data and vector data.

ArcGIS 10.5 was used to prepare the final map as well as to treat the data through geometric correction, redefining the projections available in DATUM WGS 84 for SIRGAS 2000. ArcGIS 10.5 was also used in the process of preparing the mosaic and cutting out data by delimiting the Brazilian semiarid region, defined as the study area. QGIS was used to calculate the distribution and rebalance the weights of the analysis of the hierarchical processes using the easyahp plugin (AYDINOGLU and BILGIN, 2015).

2.4 Analytic Hierarchy Process and Multicriteria

For the development of the multicriteria analysis, the work of Paiboonvorachat and Oyana (2014) was taken as a general basis, that used AHP in GIS and remote sensing software to develop a mapping methodology within the field of environmental sciences, with variables similar to those used in this work, but for purposes other than those discussed here. For mapping, we used the technique of the Analytic Hierarchy Process developed by Saaty (1990), which uses a scale ranging from 1 to 9, with the least important variable scored as 1 and as the most important variable scored as 9, as seen in Table 1. After defining the scales, the weights were balanced in the paired comparison matrix, which establishes the importance of one variable over the other.

Table 1 - Saaty scale to stabilizate values in the mapping using the AHP

Intensity of importance	Definition and Explanation
1	**Equal importance**: both factors contribute equally to the objective.
3	**Moderate importance**: one factor is slightly more important than the other.
5	**Essential importance**: one factor is more important than the other.
7	**Demonstrated importance**: One factor is strongly favored, and its greatest relevance has been demonstrated in practice.
9	**Extreme importance**: the evidence that differentiates the factors is of the greatest possible order.
2, 4, 6, 8	**Intermediate values between judgments**: there is the possibility of additional commitments.

Source: Adapted from Pinese Júnior and Rodrigues (2012).

Using the QGIS software, it is possible to assign the values of the Saaty scale and rebalance the importance of one to the other, and the same was done for the comparison matrix.

2.5 Mapping the probability of the occurrence of altitudinal rain forests in the Brazilian semiarid region

In the Brazilian semiarid region, the xerophilous vegetation and varied physiognomies are popularly known as Caatinga, which is internationally recognized as part of the Seasonally Dry Tropical Forests - STDF (PENNIGTON *et al.,* 2000). The Caatinga comprises an area of approximately 800,000 km², which corresponds to approximately 11% of the area of Brazil. In most of this area, the altitude varies between 0 and 600 m, with an average temperature of 26–28 ° C, with the maximum temperature rarely exceeding 40 °C. This area presents a pluviometric regime, where approximately half of the area of this biome receives precipitation of less than 750 mm/year, with dryer core with an average precipitation of less than 500 mm/year, and the rainfall is concentrated in three consecutive months, with a water deficit throughout the year. Although the Caatinga covers most of this semiarid space, there are punctual areas that are still little known, where higher humidity patterns allow for the development of exceptional environments (SANTOS *et al.,* 2007; ROCHA *et al.,* 2009; CARDOSO; QUEIROZ, 2010; SANTOS *et al.,* 2011; NASCIMENTO *et al.,* 2013; SILVA *et al.,* 2019).

Based on the literature and the definitions and typologies defined by Ab'Saber (1985), Tabareli and Santos (2004) and Lopes, Ramos, and Almeida (2017), we defined the variables and the importance of each variant in the process of identifying areas, such as those studied in the present work, as presented in Table 2 below. We consider an altitude of 500–1200 m to be the foremost characteristic for mapping possible areas of altitudinal rain forests, which were classified on the Saaty scale with a value of 3; for rainfall, we consider a minimum level of 1200 mm, which were classified as a value of 2; for vegetation, the last characteristic, but not for that reason unimportant, a value of 1 was used, taking into account that much of the original vegetation cover has been anthropized.

Table 2 - Partial Comparison Matrix

	Altitude	**Rainfall**	**Vegetation**
Altitude	1	2	3
Rain	0,5	1	2
Vegetation	0,333	0,5	1

Then, three classifications were defined: class number 3 corresponds to a high probability of occurrence of Altitudinal rain Forests/>30%, as it is within the parameters defined in the literature regarding the definition of what these environments are; class number 2 corresponds to a low probability of occurrence of Altitudinal Wetland Forests/<30%, class 1 corresponds to no probability of occurrence of Altitudinal Wetland Forests/0%, because the characteristics of the area differ too much. These definitions can be seen in Table 3.

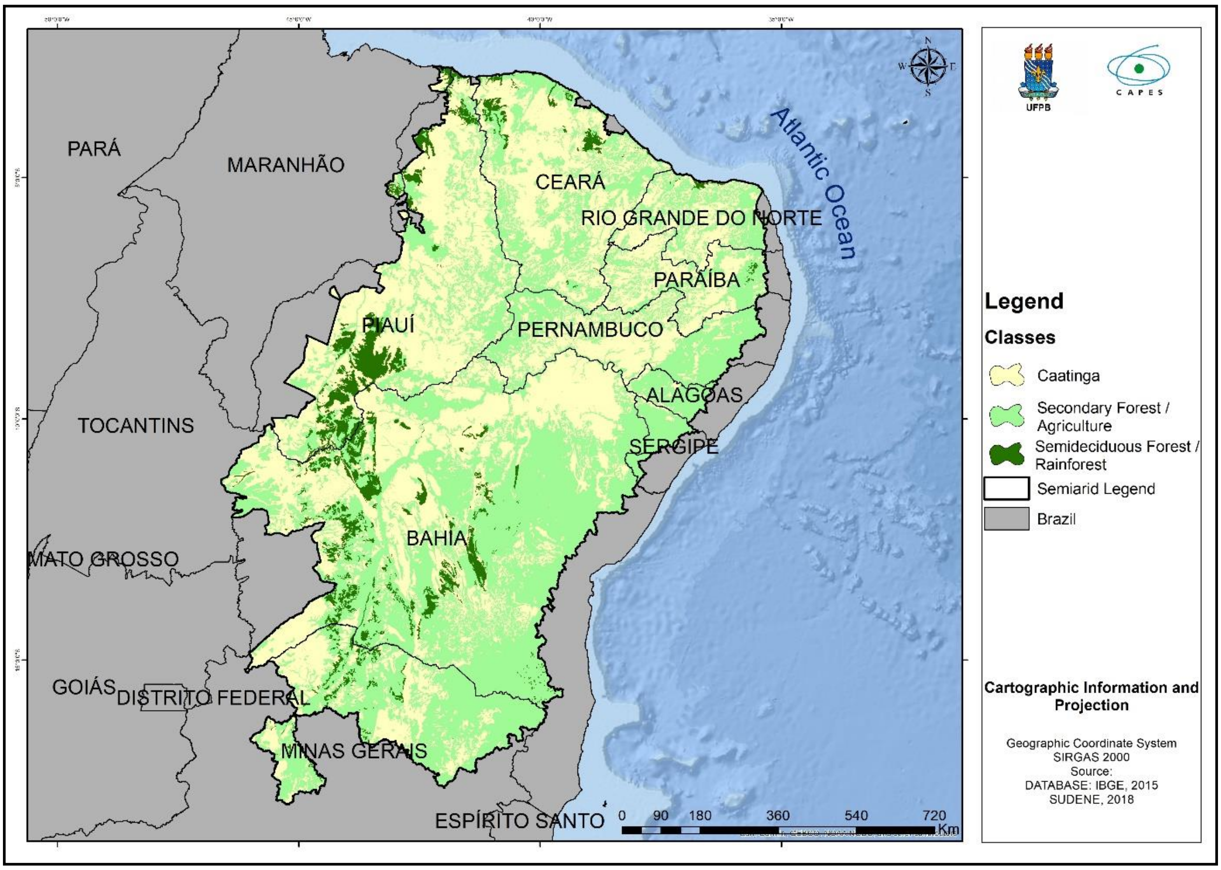
Table 3 - Definitions of Classes and Values

Assigned Classes and Values			
Class	**Altitude**	**Vegetation**	**Rainfall**
No Probability of Occurrence/0%: 1	0-300	Caatinga	0-600
Low Probability of Occurrence/<30%: 2	300-500	Secondary forest/Agriculture	600-1200
High Probability of Occurrence/>30%: 3	500-1200	Semideciduous forest/Rainforest	>1200

Finally, the Digital Elevation Model underwent reclassification to establish which class each of the altitude values belonged. A similar process occurred for the matrix data of the total rainfall of the semiarid region, while for the vector data, the definition of the class of each type of vegetation was according to a table of attributes.

Later, these vector data were transformed into matrix data for use in the esayahp tool. The resulting product in easyahp's matrix format was transformed into a vector format, and the Altitudinal Wetland Forests probability map was created with it. In Figure 2, the kinds of vegetation defined by IBGE in the Brazilian semiarid region can be seen.

Figure 2-Vegetation Map of the Brazilian Semiarid



Prepared by the authors (2020).

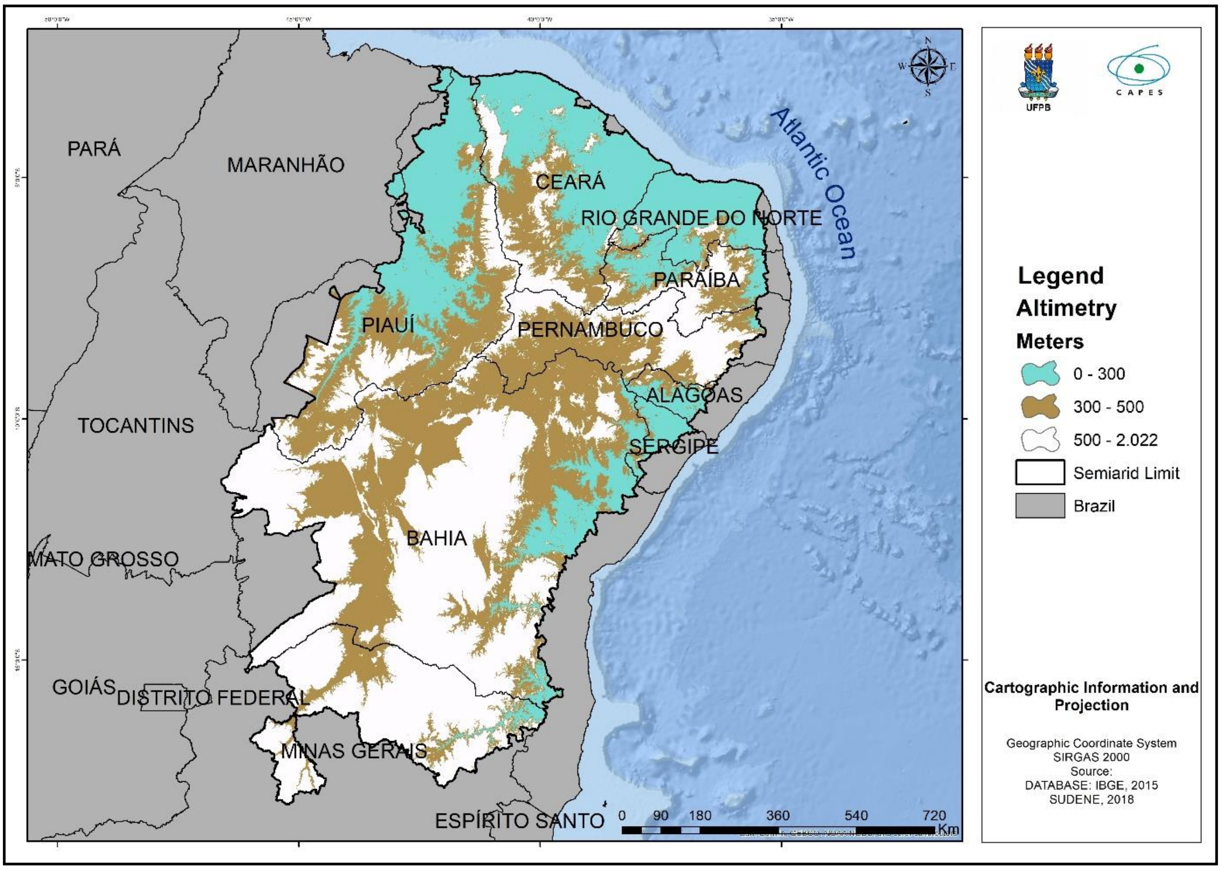
In the map in Figure 2, it is possible to observe the reclassification carried out on the vegetation data from the IBGE, which divided the vegetation cover into caatinga, secondary vegetation, agriculture, semideciduous forest, and rain forest. Since the caatinga is a biome that extends from the federative unit of Ceará to northern Brazil to the north of Minas Gerais, it can be understood that most of the time, in areas that the caatinga passes through, there is a semiarid environment (AB'SABER, 1995; SOUZA, 2015). Secondary vegetation appears in areas that have suffered deforestation and are mostly grasses. While the semideciduous forest and rain forest that can be seen on the map can be classified as humid segments, these forests are the areas where there was a retreat of vegetation from tropical areas to the interior of the Brazilian semiarid during the glaciation in the Pleistocene. Due to factors such as altitude and high rainfall, and taking into account the surrounding areas, vegetation was preserved at the end of the glacial cycle. These forests are distributed in almost all the federative units that are within the boundaries of the worked area, except for the state of

Sergipe; however, most of them are concentrated in the states of Bahia, Piauí, and Ceará, which include 88% of all semideciduous forest and rain forest that occur in the Brazilian semiarid.

3 RESULTS AND DISCUSSION

In Figure 3, the Digital Elevation Model used in the development of the work is shown, with the grades of altitude defined. In Figure 4, we show the spatialization of the total rainfall of the Brazilian semiarid, according to the definition of the three distinct classes.

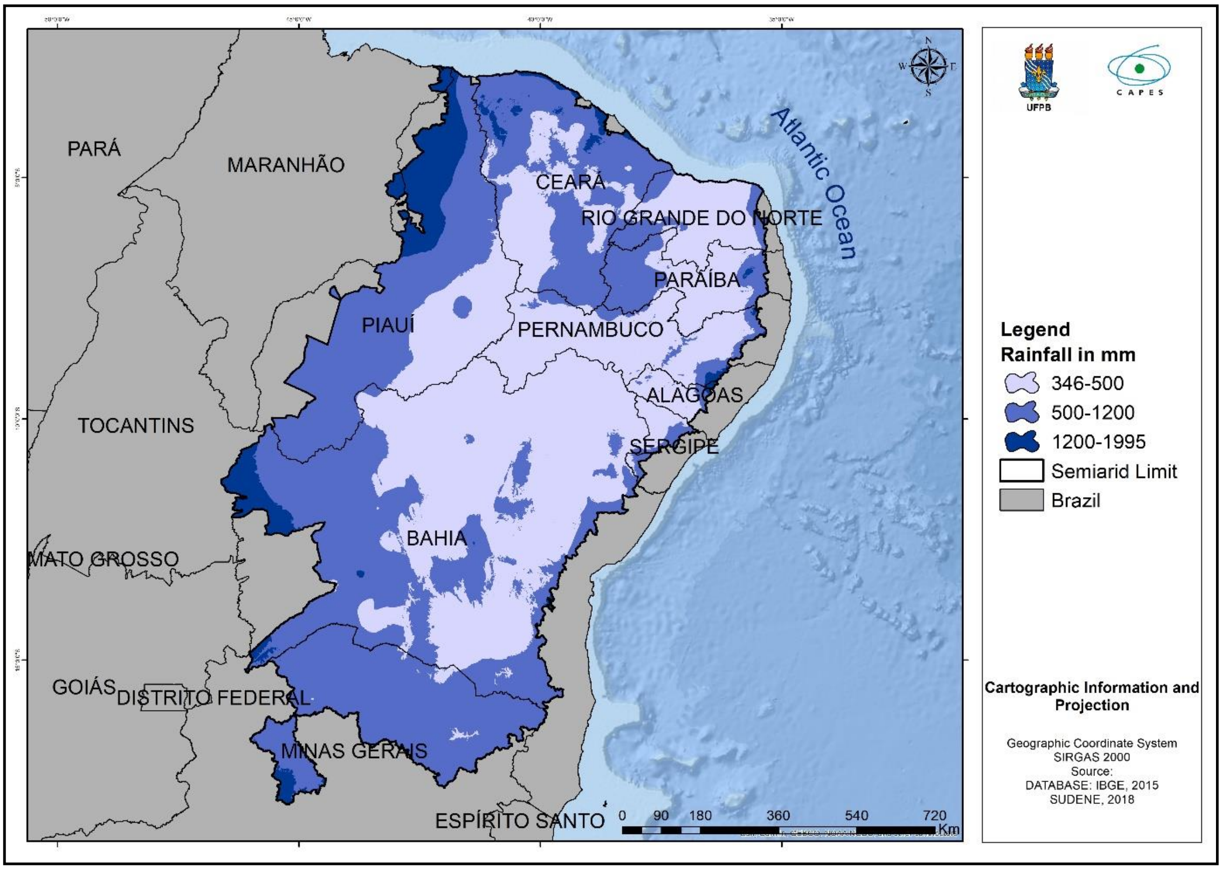
Figure 3 - Map of the Altitude of the Brazilian Semiarid



Prepared by the authors (2020).

The Brazilian semiarid has a geological structure that can be divided into a crystalline structure from the Precambrian and Pharenozoic sedimentary cover. In Figure 3, these areas appear to be the locations with the highest altitude. In the area of the Brazilian semiarid, the crystalline terrains are shown in different crystalline masses of different magnitudes, and amid these structures, there is an Interplateau Depression that comes from the Pliocene and the Quaternary, which has hills that suffer from the semiarid hot climate and seasonal drains. The Pharenozoic sedimentary covers have sedimentary terrain and are devoid of metamorphic processes. The map in Figure 3 shows the areas with the lowest elevation. The formation of these sedimentary areas was influenced by the local morphoclimatic patterns that resulted in the features of plateaus and peripheral depressions. These geological characteristics allowed the highest elevation structural formations to preserve in their area the humid forests that had formed in the interior of the continent in the last Pleistocene glaciation cycle and that when the planet started to heat, they retreated to the coastlines, leaving only these places named today altitudinal rain forests. (AB, SABER, 1974; LIMA, CUNHA, and PEREZ FILHO, 2012).

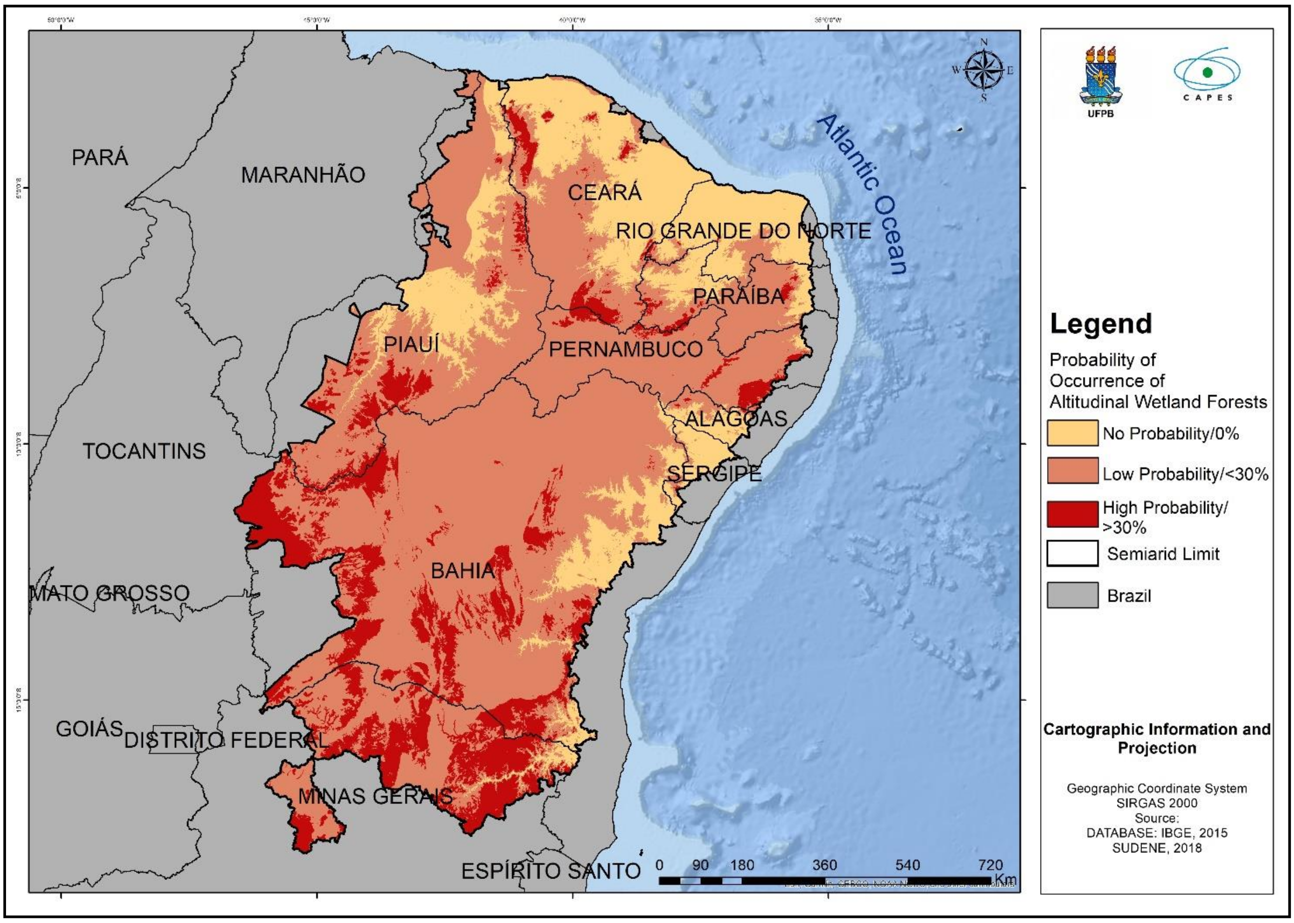
Figure 4 - Rainfall Map of the Brazilian Semiarid Region



Prepared by the authors (2020).

There is an irregularity of rainfall in the Brazilian semiarid, causing approximately 46% of the entire area to have rainfall ranging from 345–500 mm, which often occurs in a short period. Areas with less rainfall are located in the most central part of the border of the semiarid. Further from the central region, it is possible to observe an increase in the amount of precipitation, and in 48% of the semiarid, there is a rainfall of 500–1200 mm. However, there are also areas with higher levels of rainfall, as seen in the map in Figure 4, which ranges from 1200 to 1995 mm. These areas are very small compared to the other two areas occupying only 6% of the total semiarid. These locations can, at some points, be classified as wet enclaves. These areas are the places that were influenced by the cold Quaternary periods and became habitats for endemic species of tropical forests (Figure 4) (AB'SABER, 1957; BATISTA, SHIMABUKURU and LARENCE, 1997; BARBOSA and SELVA, 2001; RODRIGUES *et al.,* 2008; MARENGO *et al.,* 2014; MORATO *et al.,* 2014; MORO *et al.,* 2015; MAÇANEIRO *et al.,* 2016; SOARES-FILHO *et al.,* 2016; SOUZA *et al.,* 2018; LOURENÇO-DE-MORAES *et al.,* 2019; PREDEVELLO, 2019). The data presented in Figures 2, 3, and 4 were used to map the multicriteria, which can be seen in Figure 5.

Figure 5 - Map of the Probability of the Occurrence of Altitudinal Wetland Forests in the Brazilian Semiarid Region



Prepared by the authors (2020).

In the occurrence mapping of Altitudinal Wetland Forests, it was possible to delimit 3 types of areas: high, low, and no probabilities. In the consulted literature, some of the cataloged Altitudinal Wetland Forest can be found in the states of Paraíba, Pernambuco, Bahia, Ceará, and the Rio Grande do Norte (Tabarelli and Santos, 2004; Souza and Oliveira, 2018; Medeiros and Cestaro, 2019). Being able to show that the swamps located by these authors can be found inserted in the areas of a high probability of occurrence of altitudinal rain forests. The altitudinal rain forests described in the reference article are shown in Table 4 below.

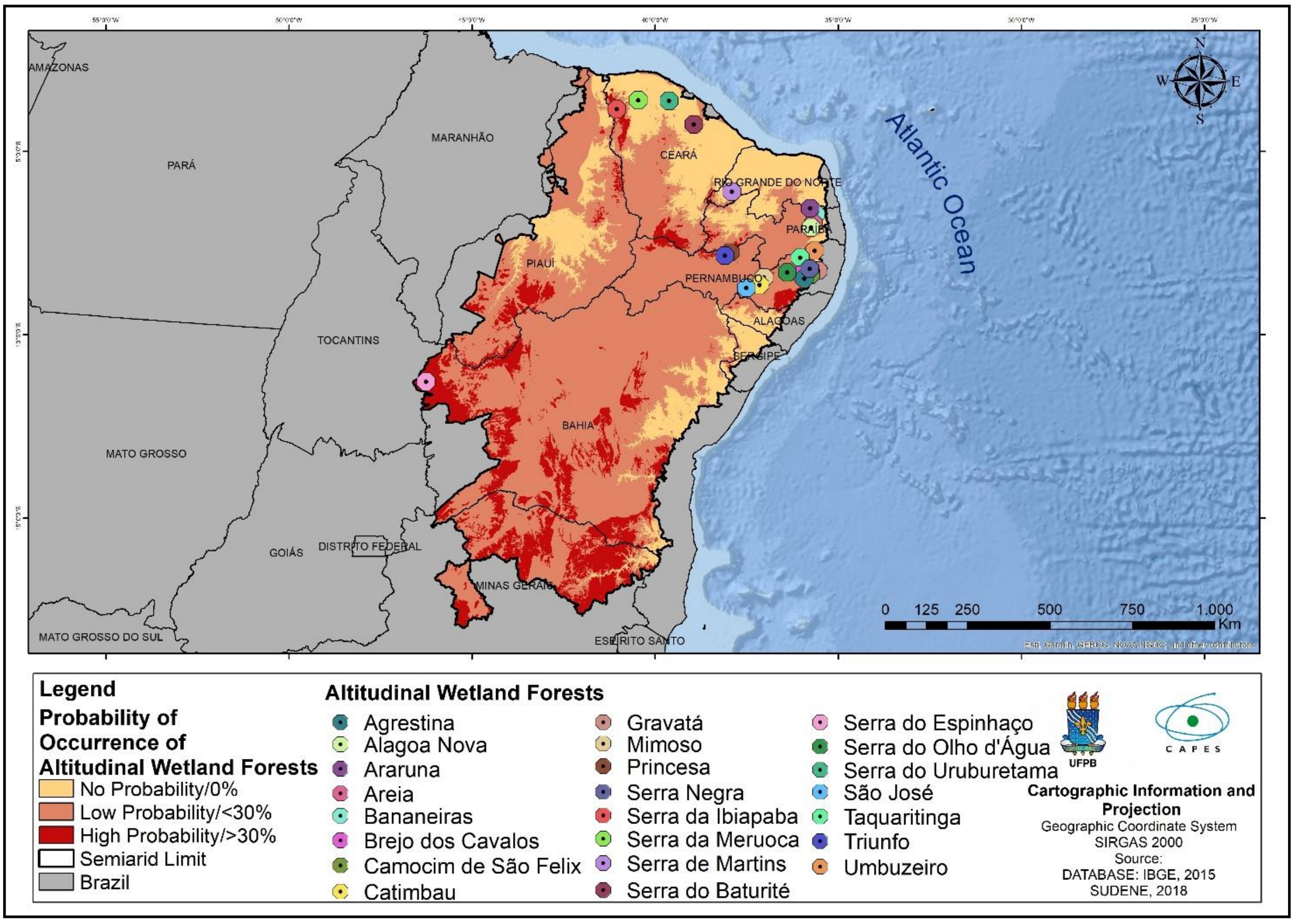
Table 4 - Altitudinal Wetland Forests in the Brazilian Semiarid

Altitudinal Wetland Forests	Town	State	Lat° S, Long° W
Bananeiras	Bananeiras	Paraíba	6° 45′, 35° 37′
Areia	Areia	Paraíba	6° 57′, 35° 40′
Alagoa Nova	Alagoa Nova	Paraíba	7° 04′, 35° 45′
Araruna	Araruna	Paraíba	6° 33′, 35° 44′
Umbuzeiro	Umbuzeiro	Paraíba	7° 40′, 35° 38′
Princesa	Princesa Isabel	Paraíba	7° 44′, 37° 59′
Triunfo	Triunfo	Pernambuco	7° 49′, 38° 6′
Mimoso	Arcoverde	Pernambuco	8° 25′, 37° 2′
Taquaritinga	Taquaritinga	Pernambuco	7° 54′, 36° 1′
Brejo dos Cavalos	Caruaru	Pernambuco	8° 16′, 35° 58′
Gravatá	Gravatá	Pernambuco	8° 12′, 35° 32′
Camocim de São Felix	Camocim de São Felix	Pernambuco	8° 21′, 35° 45′
Agrestina	Agrestina	Pernambuco	8° 27′, 35° 56′
Catimbau	Buíque	Pernambuco	8° 37′, 37° 8′
São José	Moxotó	Pernambuco	8° 43′, 37° 31′
Serra Negra	Bezerros	Pernambuco	8° 13′, 35° 46′
Serra do Olho d'Água	Belo Jardim	Pernambuco	8° 19′, 36° 25′
Serra do Espinhaço	Formosa do Rio Preto	Bahia	11º16′,45º15′
Serra da Ibiapaba	Tianguá	Ceará	3°50, 41° 3'
Serra da Meruoca	Meruoca	Ceará	3°35', 40°28'
Serra do Baturité	Guaramirangá	Ceará	4°15', 38°56'
Serra do Uruburetama	Uruburetama	Ceará	3°36', 39°37′
Serra de Martins	Martins	Rio Grande do Norte	6°50′, 37°54′

Source: Adapted from Tabarelli and Santos (2004, p. 20).

In terms of area quantified in square kilometers, there are more areas with a high probability of occurrence of Altitudinal Wetland Forests/>30%, which total 172,632.80 km², in the Brazilian semiarid, while the areas that correspond to a low probability/<30% are equivalent to 717,309.16 km². In turn, the areas with no probability of occurrence of Altitudinal Wetland Forests/0% total 241,108.39 km². Of the 23 Wetland Forests cataloged and defined by the literature used for the discussion of the present study, 18 were located within areas defined as high probability, while only 5 were located in low probability areas (Figure 6).

Figure 6 - Potential distribution of Brejos de Altitude in the Brazilian Semiarid and the main areas located in the states of Ceará, Paraíba, Pernambuco, and Bahia



Prepared by the authors (2020).

Wet Mountains that are within the high possibility areas were identified in the following locations: Serra de Martins, in Rio Grande do Norte; Serra da Ibiapaba, Serra do Baturité and Serra do Uruburetama, in Ceará; Serra do Espinhaço in Bahia, Triunfo, Mimoso, Taquaritinga, Gravatá, Catimbau, Serra Negra, in Pernambuco; and Bananeiras, Areia, Alagoa Nova, Araruna, Umbuzeiro and Princesa Isabel, in Paraíba. We emphasize that in many of the mentioned localities and municipalities, the Brejos do not cover their entire territory but are present in most of their area. Seventy-eight percent of the previously described wet mountains are in the high probability class and are within areas that are defined as Altitudinal Wetland Forests according to the relation of the variables used to carry out the mapping.

The Wetland Forests that were located in areas with a low probability of occurrence of Altitudinal Wetland Forests have very specific locations that the scale used in this work could not completely identify, as seen in Figure 6. However, as an exception, 5 Wetland

Forests were found in the low probability class, all of which are located in Pernambuco, namely: Brejo dos Cavalos, Camocim de São Felix, Agrestina, São José and Serra do Olho d'Água. These Brejos (except São José) are located in the harsh Pernambuco. Medeiros and Cestaro (2017) argue that these locations make up humid segments due to the presence of dark red, clayey, fertile, and deep soils, as well as their altitude, which varies from 800 to 1200 meters above sea level.

It is also worth noting that these Wetland Forests are located in the low probability class of the occurrence of Altitudinal Wetland Forests, and despite being arranged in locations considered to have the ideal altitude for the definition of these humid segments, their rainfall regime is not as intense as in the high probability areas. In this context, as in the localities highlighted for Pernambuco, the soil and its capacity to store water is also an element that cannot be neglected in the identification of these wetlands. Therefore, the issue goes beyond the factors of relief, altitude, and amount of rain, making the identification of these wetlands even more complex.

Despite the applied methodology using a scale of priorities, this does not take away the great relevance of the other elements considered as rain and vegetation, these characteristics being a fundamental part for the definition of areas with high probability for the occurrence of altitudinal rain forests, the altitude in a unique way and isolated from other factors does not make a given area an altitudinal rain forest, there is a need for a list of factors for this to be possible. However, it is important to note that according to Tabarelli and Santos (2004) a large part of the vegetation of these specific areas of exception was deforested for agriculture and today it forms part of what is called the secondary forest, thus changing the original environmental system of the area. In the occurrence mapping, it is possible to observe different points in Pernambuco, Paraíba, Rio Grande do Norte, Ceará and Bahia in which there is a high probability of occurrence of swamps of altitude, but the vegetation of the place is treated as secondary or is delegated to agriculture.

With new areas duly checked and defined as altitudinal rain forests alternative possibilities of care for these places are provided for the sphere of local public administration. Since it is known that altitudinal rain forests have different levels of fragility from the surrounding semiarid areas, it is necessary to make decisions in public policies so that specific care is taken with these humid forests, and thus properly monitored. So, this work took the first step in trying to locate where possibly these forests can be found, making it necessary to carry out other work in the field so that these areas are properly defined as altitudinal rain forests.

These policies could be based on the care with the reforestation of areas of altitudinal rain forests that were possibly deforested, if some small part of the biome has survived, in the future the altitudinal rain forests can be recovered, according to Silva Junior *et al.,* (2020) secondary forests were able to recover in 30 years percentage around 76% taxonomy, 84% of phylogenetic and 96% of functional diversity. Thus, showing the effectiveness of possible reforestation projects in recovering the biodiversity lost during the intense periods of deforestation in Brazil.

4 FINAL CONSIDERATIONS

With the use of techniques to develop GISs, it was possible to overlap information plans. These data crossings were used to organize the characteristics that define Altitudinal Wetland Forests in the literature for digital cartography. The use of these tools enabled the application of the hierarchical process analysis methodology to specifically discuss the humid segments in the Brazilian semiarid region. Through these techniques it was possible to develop a complete new methodology for mapping altitudinal rain forests.

The development of this work allowed us to observe the spatialization of areas with the highest and lowest probability of the occurrence of Altitudinal Wetland Forests, confirming the location of the areas mentioned in the literature, as well as others that can be configured to be framed in this type of environment or share some similarity with it.

From the data obtained in this research, it is possible to perform further studies to catalog areas that are Altitudinal Wetland Forests within the semiarid region and that have not yet been defined, as well as to exclude other areas that have this possibility but that in reality do not fit in the parameters applied here. If confirmed through fieldwork, many of these locations may contain new altitudinal rain forests never before discussed in the literature, before they disappear with possible deforestation.

Altitudinal Wetland Forests have vegetation cover, and many of the original water resources are at high risk of disappearing before they are even better understood, both from a spatial point of view and according to their dynamics. That said, there is a clear need for policies that make it possible to protect these areas, as well as monitor them.

Wetland Forests have a relevance that goes beyond their current ecological, economic, or cultural characteristics, and they are also important from scientific and didactic-pedagogical points of view, as areas that preserve heritage from the past that helped to build the dominant landscapes in the Brazilian semiarid space. Therefore, the identification and preservation of these wetlands also favor the development of paleoclimatic studies related to the transformation of biomes in South America, serving as a basis for identifying what may or may not already be occurring due to new climate changes.

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