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CLIMATIC CHARACTERISTICS AND THEIR IMPLICATIONS AMONG THE PEDOLOGICAL AND TOPOGRAPHICAL ASPECTS OF SOUTHERN BAHIA, BRAZIL

CARACTERÍSTICAS CLIMÁTICAS E SUAS IMPLICAÇÕES NOS ASPECTOS PEDOLÓGICOS E TOPOGRÁFICOS DO SUL DA BAHIA, BRASIL

CARÁCTERISTICAS CLIMÁTICAS Y SUS IMPLICACIONES ENTRE LOS ASPECTOS PEDOLÓGICOS Y TOPOGRÁFICOS DEL SUR DE LA BAHIA, BRASIL

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Abstract: In this paper, the climatic characteristics, and their advantages in the pedological and topographical aspects of the mesoregion of southern Bahia, Brazil, were evaluated. The study was developed in the territory of the Discovery Coast and Far South, located in the southern mesoregion of the state of Bahia. Temperature and precipitation data were obtained on the WordClim plataform and interpolated using ordinary kriging, these climate data were used to calculate evapotranspiration and soil water deficit. The soils were derived from the pedological mapping of Bahia, on a scale of 1: 1250000; hypsometry and slope were obtained using the Digital Elevation Model. The climatic variables with the physical attributes of the region were tested by Pearson correlation and simple linear regression. The annual precipitation is distributed between 878.8 mm /year and maximums of 1,619 mm/year, while the average annual temperature is between 22.01 °C and 26.08 °C. The greatest potential annual evapotranspiration occurs in December and January, in the areas that have the highest rainfall and average annual temperatures. The annual water deficit of water showed values of

88.8 to 178 mm observed in the south and northwest of the area. The area has a predominant elevation of up to 320 m and the relief is predominantly flat to wavy. The relationship between climatic, pedological and topographic data indicated that, spatially, low and flat areas with a predominance of latosols are associated with higher precipitation and higher temperature between April and September. The pedology in relation to water deficit, temperature and evapotranspiration did not present significant correlation, which indicates that the territorial extensions of the soil types do not directly interact with the local climatic conditions. The analysis contributes to the understanding of climatic factors and their relationships to the other physical characteristics of the south of the Bahia.
Keywords: Climate. Water déficit. Water resources.

Resumo: O trabalho objetivou avaliar as características climáticas e suas implicações nos aspectos pedológicos e topográficos da mesorregião do Sul da Bahia, Brasil. Os dados climáticos de temperatura e precipitação foram obtidos na plataforma do WordClim e interpolados por krigagem ordinária, utilizados para cálculo da evapotranspiração e déficit hídrico do solo. Os solos derivaram do mapeamento pedológico da Bahia, em escala 1: 1250000 e a hipsometria e declividade foram obtidas por Modelo Digital de Elevação. As variáveis climáticas com os atributos físicos da região foram testadas por correlação de Pearson e regressão linear simples. A precipitação anual distribui-se entre 878.8 mm/ano e máximas de 1.619 mm/ano enquanto a temperatura média anual se dá entre 22,01°C e 26,08°C. As regiões Nordeste e Sudeste apresentaram maiores precipitações no ano, assim como também foram observadas as maiores temperaturas anuais. A evapotranspiração potencial anual mais elevada ocorre em dezembro e janeiro nas áreas com maiores precipitações e temperaturas médias anuais. O déficit hídrico anual apresentou valores de 88,8 a 178 mm observados no sul e noroeste da área. A área possui elevação predominante de até 320 m e o relevo é predominantemente plano a ondulado. A relação entre dados climáticos, pedológicos e topográficos indicou que, espacialmente, áreas baixas e planas com predomínio de Latossolos estão associadas a maior precipitação e maior temperatura entre abril e setembro. A pedologia em relação ao déficit hídrico, a temperatura e a evapotranspiração não apresentaram correlação significativa, indicando que as extensões territoriais dos tipos de solo não interagem diretamente com as condições climáticas locais. A análise contribui para uma compreensão dos fatores climáticos e suas relações com as demais características físicas do Sul da Bahia.
Palavras-chave: Clima. Déficit Hídrico. Recursos hídricos.

Resumen: El objetivo de este trabajo fué evaluar las características climáticas y sus implicaciones en los aspectos pedológicos y topográficos de la mesorregión del sur de la Bahía, Brasil. Los datos climáticos de temperatura y precipitación se obtuvieron en la plataforma WordClim y se interpolaron mediante kriging ordinario, utilizado para calcular la evapotranspiración y el déficit hídrico del suelo. Los suelos se derivaron del mapeo pedológico de la Bahía, en escala 1:1250000, la hipsometría y pendiente se obtuvieron mediante Modelo Digital de Elevación. Las variables climáticas con los atributos físicos de la región se probaron mediante correlación de Pearson y regresión lineal simple. La precipitación anual se distribuye entre 878,8 mm/año y máxima de 1.619 mm/año mientras que la temperatura media anual se sitúa entre 22,01°C y 26,08°C. Las regiones noreste y sureste tuvieron las mayores precipitaciones del año, así como las temperaturas anuales más altas. La evapotranspiración anual potencial más alta ocurre en diciembre y enero en áreas con mayor precipitación y temperaturas anuales promedio. El déficit hídrico anual presentó valores de 88.8 a 178 mm observados en el sur y noroeste del área. El área tiene una elevación predominante de hasta 320 m y el relieve es predominantemente plano a ondulado. La relación entre los datos climáticos, pedológicos y topográficos indicaron que, espacialmente, las áreas bajas y planas con predominio de Latosoles se asocian con mayor precipitación y mayor temperatura entre abril y septiembre. La pedología en relación al déficit hídrico, temperatura y evapotranspiración no presentaron correlación significativa, mostrando que las extensiones territoriales de los tipos de suelo no interactúan directamente con las condiciones climáticas locales. El análisis contribuye a la comprensión de los factores climáticos y su relación con otras características físicas del sur de la Bahia.

Palabras clave: Clima, Déficit hídrico, Recursos hídricos.

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INTRODUCTION

The lack of data on a region represents a weakness in the planning of activities with social, promotion, cultural and natural consequences. Without the perception of several characteristics of the region, it becomes a risky to correct land-use planning, because it provides a disordered models of occupation that fade the understanding of the effects on the environment. (PEREIRA, 2000; SILVA et al., 2020).

The combined uses of different activities have sought to minimize the environmental impacts of many historical conflicts, which are taken up in the conflict between conservation and development, taking advantage of natural resources and the support capacity of ecosystems. Brazil has been trying to adopt the approach of mitigation and climate adaptation measures, since, in the long term, the impacts of climate variation will reproduce effects on water resources, energy and agriculture, were the Northeast region being among the most affected (OBERMAIER; ROSA, 2013; ARAÚJO et al., 2014; MATOS et al., 2019).

However, in the South of the State of Bahia, land use and water resource conflicts have affected the population life quality, whether due to environmental degradation or restrictions in the fundamental services policy, lack of regularization of conservation units, disorderly occupation, excessive use of water supplies for agricultural and forestry activities (SEI, 2008).

Many studies have focused attention to the North and Northeast of Brazil, areas of relevant international visibility, whether due to water abundance, such as the Amazon, or water deficit, such as the semi-arid northeast. In the Amazon, anthropic activities and high land use change, occurrence of fires and fires have been investigated for the impact on climatic conditions (CHENG et al., 2013; DUARTE et al., 2017), as well as their effects on river basins (SANTOS et al., 2018), while in the Northeast (SILVA et al., 2020), the rapid changes in land use have encouraged similar investigations, mainly due to the regional water scarcity (RAGAB; MONTENEGRO, 2012; OBERMAIER; ROSA, 2013; SILVA et al., 2021).

These areas comprise the Brazilian coastal zone, which has 26.6% of the population of Brazilian municipalities, equivalent to 50.7 million inhabitants and allocates large urban centers with the highest density of activities and use of resources (IBGE, 2011). Specifically in the Northeast, it is characterized by tropical and subtropical climates, receiving influences from the El Niño Southern Oscillation (ENSO), Intertropical Convergence Zone (ITCZ), South

Atlantic Convergence Zone (SACZ), also synoptic scale, such as frontal systems and upper levels cyclonic vortex, and also local scale systems, such as breezes, as well as characteristics of topography, vegetation, distance or proximity to the sea (PARRY, 1988; CHAVES, 1999; SAAVEDRA; CALVO; JIMENEZ, 2011; OLIVEIRA et al., 2016; PEREIRA; MOURA; LUCENA, 2020).

However, the distribution of precipitation in the northeastern semi-arid regions, is low compared to the east (coast), which exceeds 1500 mm (REBOITA et al., 2016). Silva and Oliveira et al. (2017) also observed greater precipitation in the coastal line of the Northeast compared to the semi-arid regions, predisposing the region to restrictions regarding the use and management of water resources.

Thus, the South of Bahia as a coastal region, becomes important to understand the climatic characteristics, justified by being a place of strong climate dependence in its economic activities, which are distributed among tourism, agriculture and forestry (SILVA et al., 2021). Where, there is a great interaction in the dynamics of land use change by the forestry expansion production, given that the climatic conditions are suitable for the forest sector, with reduced monthly water availability only in February and March (AGUIAR et al., 2020; SILVA et al., 2020), and in some areas, the high relative humidity can induce problems in the productivity (SILVA et al, 2009).

For Jardim (2017), situating the real spatial-temporal changes in terrestrial environments scales, including climate, is a fundamental component for organizing the impacts produced by such effects on the environmental system. In other words, climate variations due to the environmental characteristics of Brazilian regions can be analogous to any climate change or whatever its consequence, both by natural variations and human activities (IPCC, 2007).

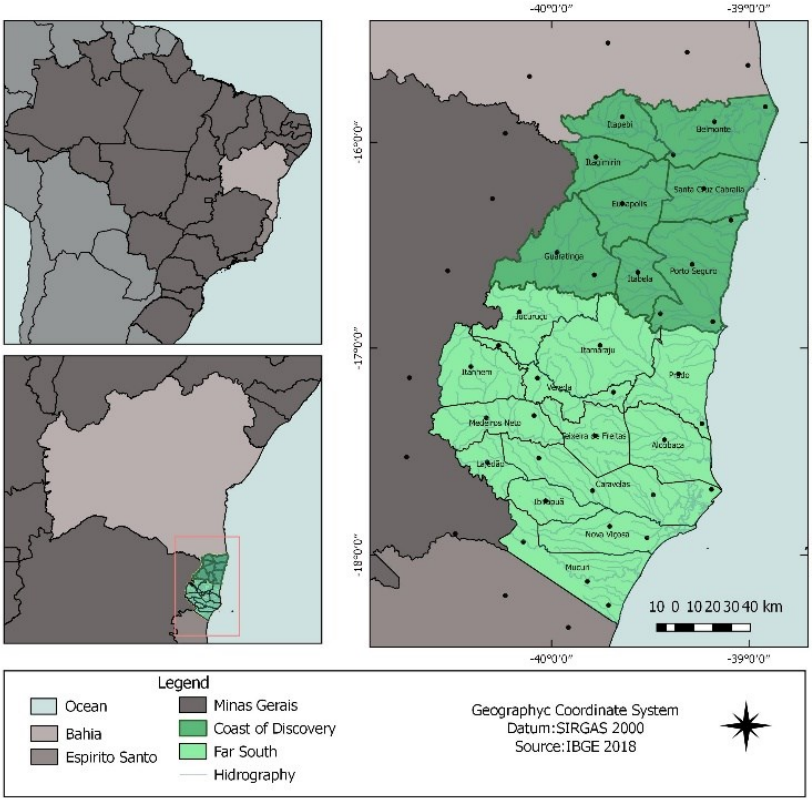
In this sense, this work evaluates the climatic characteristics and their implications in the pedological and topographic aspects of Southern Bahia, Brazil, aiming to contribute to a management of the agricultural and forestry activities areas, as well as to mediate decisions about negative influences on the depletion of water resources.

MATERIAL AND METHODS

Study area

In this study, we studied the central Southern region of the State of Bahia, formed by the Identity Territories of the Discovery Coast and Extreme South, composed of 21 municipalities, it is located in the northeastern region of Brazil and includes seventy municipalities in a territory of 54,642.35 km² and a population above 2 million inhabitants, as shown in Figure 1 (SEPLAN, 2018).

Figure 1 - Location map of the Extreme South and Discovery Coast.



Source: Elaborated by the authors (2020)

The economy is diversified, including agriculture in the extraction of cocoa, palm, coconut, industry, tourism and forestry. The State is considered the fourth producer in the country in eucalyptus forestry, and the region studied being the main state producer (WANDERLEY; SAINTS; PORTUGAL, 2014; IBA, 2015). The area is located exclusively in the Atlantic Forest domain and has about sixty conservation units, in addition to being inserted in the planning region of the basins of the Buranhém, Frades, Santo Antônio, Riacho Doce, Mucuri, Jucuruçu, Peruípe and Itanhém rivers.

The territory of is characterized by a territorial area of 12,132 km², population projection of 407,205 inhabitants for 2020 and eight municipalities, being Belmonte, Eunápolis, Guaratinga, Itabela, Itagimirim, Itapebi, Porto Seguro, Santa Cruz Cabrália. The Extreme South is characterized by 18,536 km² of area, 481,232 inhabitants projected in 2020 and 13 municipalities, being Alcobaça, Caravelas, Ibirapoã, Itamaraju, Itanhém, Jucuruçu, Lajedão, Medeiros Neto, Mucuri, Nova Viçosa, Prado, Teixeira de Freitas, Vereda (SEI, 2019).

According to the koppen climatic classification (DUBREUIL et al., 2018), the climate changes from Af (Humid or super humid tropical climate, presenting precipitations greater than 1,500 mm/year) to, Am (Humid or subhumid tropical climate), Aw (Tropical climate with dry winter and precipitation reaching 1,800 mm/year), As (Tropical climate with dry summer season), Cwa (Subtropical climate of dry winter and hot summer) Csb (Humid temperate climate with winter rains moderately hot summer, precipitations up to 1600 mm) in the Extreme South and Discovery Coast (ALVAREZ et al., 2013).

METHODS

Climate Data

Climatic data, precipitation and temperature were obtained free of charge on the wordclim's global climate database (version 1.4, https://www.worldclim.org/data/index.html), downloaded the data for Brazil in a series equivalent to 50 years (1950-2000) with resolution of 30 arc-sec (~90m) (HIJIMANS et al., 2005).

A grid of 49 points was generated, randomly distributed in the interior and in the border areas of the study, outlining the dimensions of the State of Bahia, Minas Gerais and Espírito Santo, used to extract the average precipitation and temperature, as shown in Figure 1.

After that, the data were interpolated by ordinary kriging (GROHMANN, et al., 2008) and segmented for the study area. Kriging is used to know the value of a variable at points that have not been sampled from sampled points, based on the spatial dependence that measurements separated by small distances tend to be more like each other (SOUZA et al., 2001; LIMA et al., 2006; GROHMANN, et al., 2008). The treatment and processing of data were all carried out using the free software QGIS version 2.18.21.

The rates of evapotranspiration and soil water deficit (Equations 1-8) were calculated using the method proposed by Thornthwaite and Mather (1948). Evapotranspiration expresses the process of evaporation and transpiration that occur simultaneously and naturally on vegetated soil without any water deficit, through the following expressions (PEREIRA; ANGELOCCI; SENTELHAS, 2007; SENTELHAS; SANTOS; MACHADO, 2008; ALVES; MARTINS; REBOITA, 2020).

$$ETPx = 16.\left(10.\frac{Tmed}{I}\right)^{a} \text{ for } 0 \leq \text{Tmed} \leq 26.5 \quad (1)$$
$$ETPx = -415.85 + 32{,}24.Tmed - 2 \quad for\ Tmed > 26.5 \quad (2)$$
$$\text{I}=\sum_{n}^{12} = 1\ (0.2Tmed)^{1{,}514} \quad (3)$$
$$\text{a} = 6.75 * 10 - 7 * \text{I}3 - 7.71 * 10 - 5 * \text{I}2 + 1{,}.792 * 10 - 2 * \text{I} + 0.49239 \quad (4)$$
$$N = \frac{2}{15} * ar\cos[-1(tg\varphi * tg\delta)] \quad (5)$$
$$\text{Ci} = \frac{N}{12} * \frac{NDPi}{30} \quad (6)$$
$$ETP = ETPx * Ci \quad (7)$$
$$DEFi = ETPi - ETRi,\ for\ (Pmed - ETP)i < 0 \quad (8)$$

where,

$ETPx$ is the potential evapotranspiration not corrected for *the i-th month* considered (*i* = 1 to 12) (mm/month); ETP is the potential evapotranspiration corrected for *the i-th month* considered (mm/month); $Tmed$ is the climatological mean of the average air temperature of the *i-th month; I* is the annual heat index; *a* is a regional thermal index; *Ci* is the correction factor; *NDPi* is the number of days *of the i-th* month; *Ni* is the photoperiod of the 15th day of the *i-th month,* considered representative of the monthly average; φ is latitude and δi is the solar declination of the 15th day of *the* first month; $ETRi$ is the actual evapotranspiration (ALVES; MARTINS; REBOITA, 2020).

The dry season for this region, were considered the months of April to September, while the rainy season from October to March, (SEI, 1998; SILVA et al., 2011; AGUIAR et al., 2020). Occurring by the conduction of the South Atlantic Convergence Zone (SACZ) in the region 12°S-15°S, and its presence with discontinuous activity, is the reason of the rainy season (November to March) of the South of the Northeast. On the other hand, there are some events of the SACZ that are linked to a cyclone in the South Atlantic Ocean, these cyclones have as a source of humidity the Amazon, and the tropical sector of the South Atlantic Ocean (SILVA; REBOITA; ESCOBAR, 2019).

Pedological and topographic data

The spatial and pedological information of Bahia was acquired free of charge in the spatial format on the website of the Institute for the Environment and Water Resources of Bahia (http://www.inema.ba.gov.br/wp-content/files/MTematico_solos.pdf). The scales of this information are 1:1,250,000 and segmented to southern Bahia.

The topography was analyzed by the acquisition of a Digital Elevation Models (DEM) of the Shuttle Radar Topography Mission (SRTM) project, downloaded free of charge on the TOPODATA/INPE website (http://www.dsr.inpe.br/topodata/access.php).

The DEM was carried out for hypsometric analysis, classifying the model into altimetry ranges, as well as slope analysis into percentage values, according to Embrapa (2018) which classifies the terrain in flat-to-steep relief. Data analysis and processing were performed in the free software QGIS version 2.18.21, in a field analysis processing module.

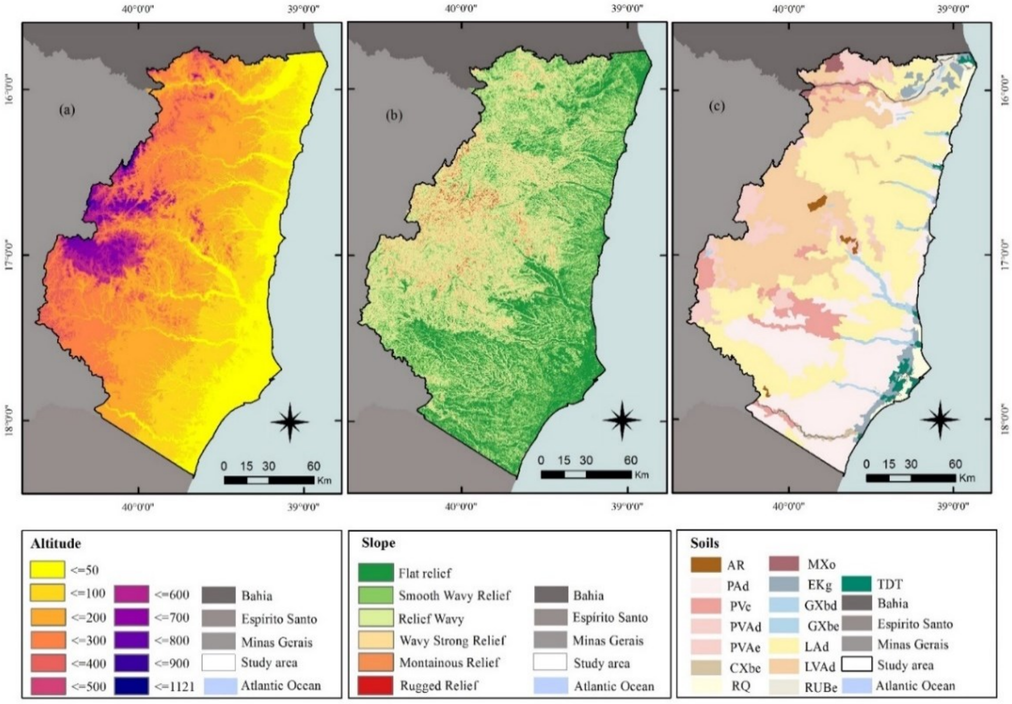
RESULTS AND DISCUSSION

Pedological and topographic description

The pedological and topographic aspects are conditioning factors for the understanding of climatic aspects, specifically the process of infiltration of precipitation in the soil, surface runoff interference and the relationship between evapotranspiration and vegetation cover. The spatial distribution of these factors is shown in Figure 2.

Hypsometry showed an altimetric amplitude that ranged from 0 to 1,121 m, according to Figure 2a. In the area, 92.69% is represented by altitude between 0-320 m, covering 28,732.88 km^2. Only 0.10% of the area has an altitude above 800 m, according to Table 1. The areas with the highest altitude are in the northwest and southwest and bordering the states of Espírito Santo and Minas Gerais.

Figure 2 - Pedological and topographical aspects in the Discovery Coast and Extreme South of Bahia. (a) Hypsometry (Altitude). (b) Slope. (c) Pedology. Source: EMBRAPA and INEMA.



Source: Elaborated by the authors (2020)

Table 1 - Hypsometric (amplitude) in the area of the Discovery Coast and Extreme south of Bahia, Brazil.

Altitude (m)	Area (km^2)	Area (%)	Altitude (m)	Area (km^2)	Area (%)
0-20	1,916.60	6.18	200-220	1,507.63	4.86
20-40	2,092.07	6.75	220-240	1,447.16	4.67
40-60	2,702.15	8.72	240-260	1,214.02	3.92
60-80	2,786.24	8.99	260-280	940.94	3.04
80-100	2,738.01	8.83	280-300	839.79	2.71
100-120	2,202.65	7.11	300-320	849.98	2.74
120-140	1,867.58	6.02	320-400	654.20	2.11
140-160	1,789.04	5.77	400-600	1,356.98	4.38
160-180	1,709.34	5.51	600-800	739.14	2.38
180-200	1,612.50	5.20	800-1121	31.33	0.10

Source: Elaborated by the authors (2020)

The slope of the area showed relief varying between flat and steep, denoting the peculiar characteristic of coastal areas and its variation along the continent, as shown in Figure

2b. The relief is predominantly flat to wavy, representing 80.28% of the study area. Quantitative characteristics can be seen in Table 2.

Table 2 - Quantitative slope in the area of the Discovery Coast and Extreme South of Bahia, Brazil.

Slope (%)	Discrimination	Area (km²)	Area (%)
0 – 3	Flat relief	8,154.44	24.84
3 - 8	Gently wave relief	8,420.45	25.65
8 - 20	Wavy relief	9,778.54	29.79
20 - 45	Strongly wavy relief	5,850.48	17.82
45 - 75	Mountainous relief	533.87	1.63
> 75	Rugged relief	89.13	0.27

Source: Elaborated by the authors (2020)

It was found that the steeply undulating relief is located to the northwest and southwest, which also have the lowest temperatures. Point areas on the coast have reliefs above 45% of slope, among them the southwest portion of Porto Seguro, where the Monte Pascoal National Park is located.

The relief is directly related to land use processes and changes in climate conditions over time. According to Monteiro (2009), areas with high slope but with the presence of vegetation tend to reduce soil compaction and favor water infiltration through the roots, while the absence of vegetation leads to greater surface runoff, erosion and leaching. For Ribeiro (2009), the slope is also related to rainfall and temperature, influencing the occurrence of orographic rains. In the area, orographic rains are common in the western region, as an example of the city of Guaratinga, which has a complex of mountain ranges and undulating relief.

The local pedology is shown in Figure 2c, the most common soil is the Dystrophic Yellow Latosol, in an extension of 37.79% of the area and predominantly in the northeast and south of the study area. The Dystrophic Yellow Ultisol is found along the south and coast of the study area and the Dystrophic Red-Yellow Latosol to the northwest and central-west, representing the second and third largest soil classes. The distributions of the other pedological classes can be seen in Table 3.

Argisol soils are characterized by the presence of mineral material, with a textural B horizon immediately below the A or E and of variable depth, from strong to imperfectly drained, with greater predisposition to erosion, which impacts areas with higher rainfall incidence if associated with anthropic uses without adequate management. Oxisols, on the other hand, are mineral material, with a latosol B horizon and advanced weathering stage (EMBRAPA, 2018). According to the Brazilian Soil System (2018), these latosols are typical of tropical and subtropical regions, being deep and heavily drained, predominantly in flat and smooth undulating relief.

Table 3 - Soil quantity in the area of the Discovery Coast and The Extreme South of Bahia, Brazil.

Pedology	Abbreviations	Area (km^2)	Area (%)
Dystrophic Yellow Latosol	Lad	1,2021.82	37.79
Dystrophic Yellow Argisol	Pad	7,116.26	22.37
Dystrophic Red-Yellow Latosol	LVAd	6,031.17	18.96
Red Argisol	PVe	1,558.75	4.90
Dystrophic Yellow Argisol	PVAD	1,230.52	3.87
Strophic Red-Yellow Argisol	PVAe	932.07	2.93
Hydromorphic Spodosol	EKg	736.91	2.32
Haplic Gleysol	GXbd	631.07	1.98
Quartzarenic Neosols	RQ	548.62	1.72
Terrain Types	TDT	287.50	0.90
Fluvic Neosol too Eutrophic	RUBe	271.20	0.85
Chernosolo Haplico	MXo	145.24	0.46
Haplic Cambisol too Eutrophic	CXbe	136.28	0.43
Eutrophic Haplic Gleysol	GXbe	30.56	0.10
Rocky outcrop		137.35	0.43

Source: Elaborated by the authors (2020)

As they occupy about 57% of the southern Bahia territory, latosols are the most used in anthropogenic activities and can be considered the most important in the central region. The high use results from its physical characteristics associated with its proximity to the coastal line, which combined with a well-distributed rainfall and temperature, cooperate for the development of dense activities and economic services in the region. In agricultural use, the only restriction for crop development is the low natural fertility that can be compensated with corrective management and fertilization.

Climatological description

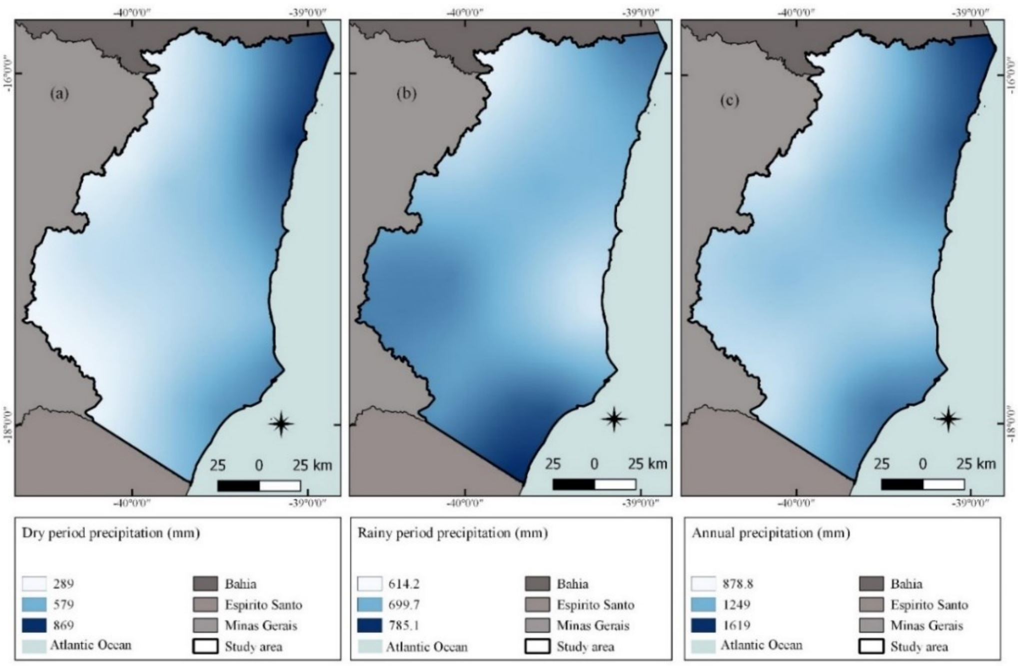
The climatic characterization of the Discovery Coast and the Extreme South of Bahia allows us to understand the average annual variation of the municipalities located south of the Bahia and bordering the states of Minas Gerais and Espírito Santo, states with characteristics in their climatic and environmental conditions, specifically when considering the analyzes in the coast-continent direction.

The climate is generally marked by conditions of low precipitation, high air temperatures and high evaporation rates (SILVA et al., 2006). However, the highest rainfall occurs in southeastern Bahia and according to Kousky (1979), Rao et al., (1993), Silva et al., (2011) and Aguiar et al (2020) is presented in December and January. This study showed greater rainfall between the months of October to December (rainy) with rainfall above 100 mm/month. It was noted that the standardization of climatic periods in this region, in a way, is governed by each season and is not restricted to a phenomenon, but to a set of factors that form the dry and rainy periods of this region, as can be seen in Figure 3.

In the dry season, the accumulated precipitation varied between 869 mm and 289 mm (Figure 3a). Municipalities with lower rainfall were observed in the southwest, in Itanhém, Medeiros Neto, Lajedão, Ibirapuã and west of Mucuri, Caravelas, Itapebi, Itagimirim and Guaratinga. The influence of the South Atlantic Subtropical High (SASH) coincides with the presence of the trade winds, causing a strong divergence in the Northeast coast and their flow to continental spaces (CHAVES, 1999). The cold fronts, in addition to lowering the temperature in the region, are also air masses that influence the incidence of precipitation in the coastal region and the southernmost part of the region, with the maximum precipitation in winter, it is linked to the greater activity of circulation of breeze that advects cloudiness to the continent, as well as the actions of cold fronts that propagate from the southeast along the coast (KOUSKY, 1979; REBOITA et al., 2016).

The rainy season is distributed between 614 and 785 mm, indicating a minimum distribution of rainfall in Prado, Itapebi and Itagimirim while the highest rainfall is found in Mucuri, Belmonte, Nova Viçosa, Caravelas, Ibirapuã, Lajedão, Medeiros Neto, Itanhém and west of Vereda (Figure 3b).

Figure 3 - Precipitation on the Discovery Coast and Extreme South of Bahia, Brazil. (a) Dry season precipitation (April to September). (b), Rainy season precipitation (October to March). (c) Annual rainfall.



Source: Elaborated by the authors (2020)

The distribution of annual precipitation denotes a smaller amount of rainfall in the northwest and southwest, with minimums of 878.8 mm/year and maximums for the northeast of 1,619 mm/year (Figure 3c). In the northeast and southeast, the annual rate coincides with that observed by Dourado et al., (2012) who indicated the coastal zone of Bahia with average rainfall of 1,363 mm/year.

The precipitation presented by Silva et al (2011), in Bahia were 978 mm annually, these precipitation data are lower compared to the data of this study, where it is possible to observe average values of 1,400 mm/year in precipitation on the Discovery Coast and Extreme South. The municipalities with minimum rainfall accumulated in the year were Itapebi, Itagimirim, Guaratinga, Lajedão and west of Mucuri and Ibirapuã and the maximum, the municipalities of Belmonte, Santa Cruz Cabrália, Porto Seguro, in the eastern region of Nova Viçosa, Mucuri and Caravelas.

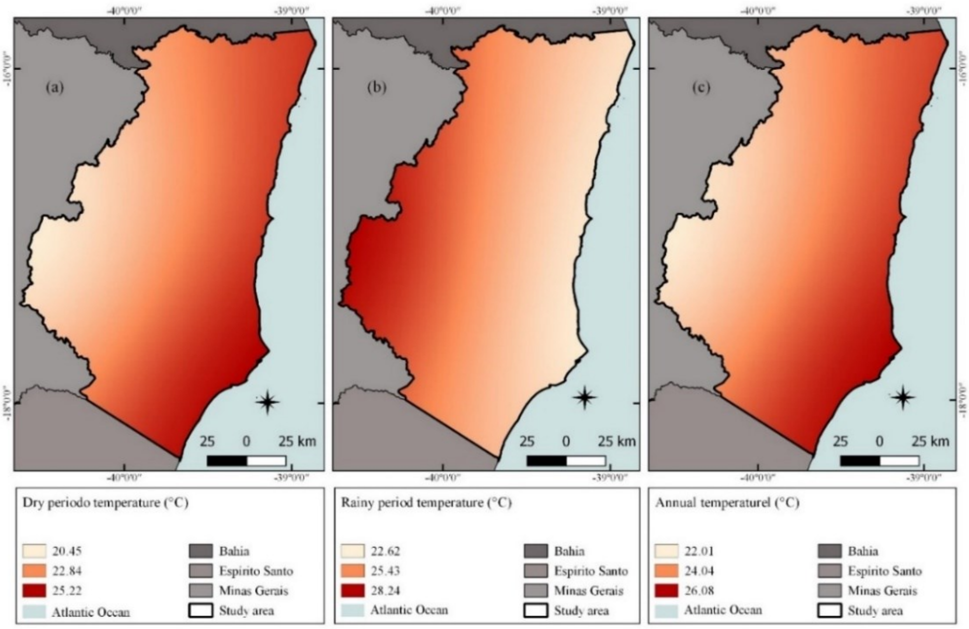
In summer, due to the increase in the pressure gradient between the continents and the ocean, there is an intensification of the northeast trade winds that bring moisture to South America, at the same time as the South Atlantic Convergence Zone (SACZ) (TASCHETTO, 2006), that generates precipitation, being characterized by a band of cloudiness that transmits humidity and extends from the Amazon region to the Subtropical Atlantic in spring and summer (CHAVES, 1999) for this southern region of Bahia. Near the coast, precipitation is more homogeneous, with rainfall distributed throughout the year due to the frontal systems, and in the longest longitudes from 40°W onwards, there is a greater influence of SACZ (CHAVES, 1999), resulting in a well-defined annual cycle (Figure 3b and c).

However, the regionalization of annual precipitation cycles in the South American climate atlas, the Discovery Coast and the Extreme South of Bahia are in the regionalization five "R5" (northeast and southeast of Brazil, including Ecuador and Northern Peru). This region is divided into three sectors and the present study area is in the southeastern sector, a region characterized by wet and dry summer in winter, observing a convective activity in the summer period and low rainfall in winter (REBOITA et al., 2010).

Figure 4 shows the temperature distribution for the Discovery Coast and the Extreme South of Bahia. The average annual temperature is between 22°C in the west and 26°C southeast of the south coast. It was observed the similarity of this distribution with the study by Lima et al. (2011), which demonstrated a temperature amplitude between 22-26°C, with difference in its distribution to the State of Bahia. Zanella (2014) reinforced that in northeastern Brazil it is common to occur in temperatures ranging from 26 and 28°C (OLIVEIRA et al., 2016).

In the rainy season, the lowest temperatures were observed in the eastern region (Figure 4a), opposite the dry period that showed lower values to the west (Figure 4b). The highest mean temperature (28.2°C) was observed in the rainy season while the average temperature was in the dry period (20.4°C). The observed for the rainy season corroborates the findings of Moura and Shukla (1981), when explaining that the hottest sea surface temperatures and the increase in evaporation over the ocean influence the convergence of moisture flow and precipitation over the northeast, reflecting the higher values between October and March.

Figure 4 - Average temperature on the Discovery Coast and Extreme South of Bahia. (a) Temperature in the dry period (April to September). (b) Temperature in the rainy season (October to March). (c) Annual temperature.



Source: Elaborated by the authors (2020)

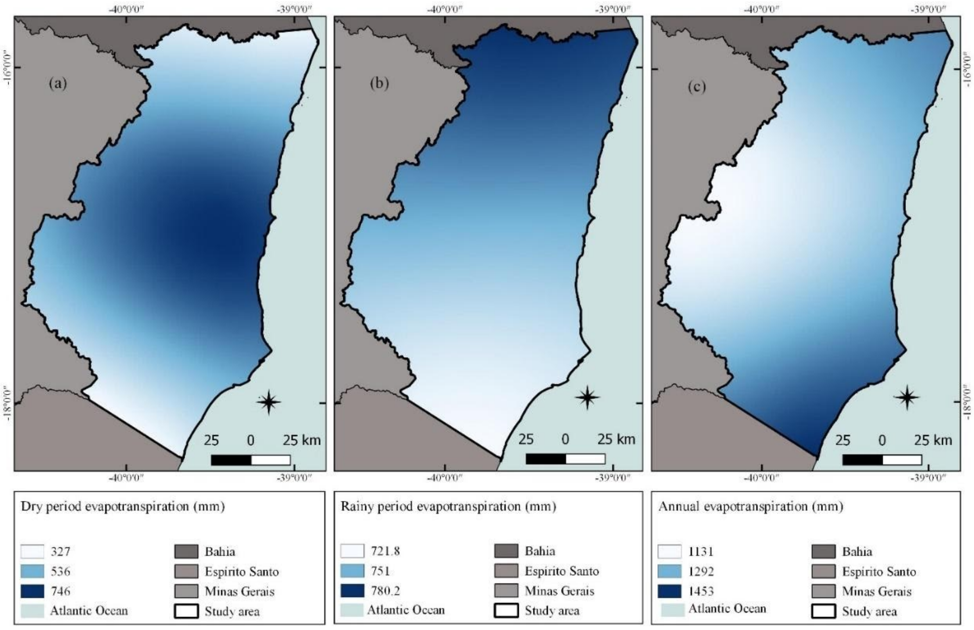
The municipalities of Prado, Mucuri, Nova Viçosa, Caravelas and Alcobaça presented maximum temperature values while the minimum values were observed in Guaratinga, Jucuruçu, Itanhém, west of Medeiros Neto and Vereda. There is an extensive area with average annual temperatures above 24°C, since both the Discovery Costa and the Extreme South of Bahia have a high annual thermal variation. This variation was also demonstrated by Moura and Shukla (1981), emphasizing the importance of sea surface temperature in determining precipitation over northeastern Brazil, whose anomalies can be influenced by location.

The lower temperatures can be explained by a greater heating of the air that generates the activation of the breeze trend and convection in the local convergence zone (KOUSKY, 1979; REBOITA et al., 2010; REBOITA et al., 2016). As a result, the months of June and July have the lowest temperatures for the area. In these months, the sun is farther away from the Zenith, consequently the radiation is lower and there is also the presence of cold fronts (NIMER, 1989). On the other hand, Silva et al. (2006) indicates that the temperature is also affected by the North Atlantic Subtropical High, justifying the discrepancy between west and east temperatures. Once, when the North Atlantic subtropical high intensifies, trades winds also intensify, and convergence increases at low levels.

The climatic influence on the earth's surface can be analyzed by variations in evapotranspiration and soil water deficit. Evapotranspiration can be seen in Figure 5. In the dry period (Figure 5a), evapotranspiration occurs from 327 to 746 mm while in the rainy season (Figure 5b), evapotranspiration ranging from 721.8 to 780.2 mm was observed. The reduced values in the dry period are due to the low amount of rain in the area and the lower temperatures.

Evapotranspiration is related to the amount of water in an area. The study by Silva et al. (2003), when investigating the water potential for three woody species, demonstrated that the availability of water in the soil greatly increased evapotranspiration when compared to temperature, relative humidity, photosynthetically active radiation and pressure and vapor deficit.

Figure 5 - Evapotranspiration (mm) on the Discovery Coast and The Extreme South of Bahia. (a) Evapotranspiration in the dry period (April to September). (b) Evapotranspiration in the rainy season (October to March). (c) Annual evapotranspiration.



Source: Elaborated by the authors (2020)

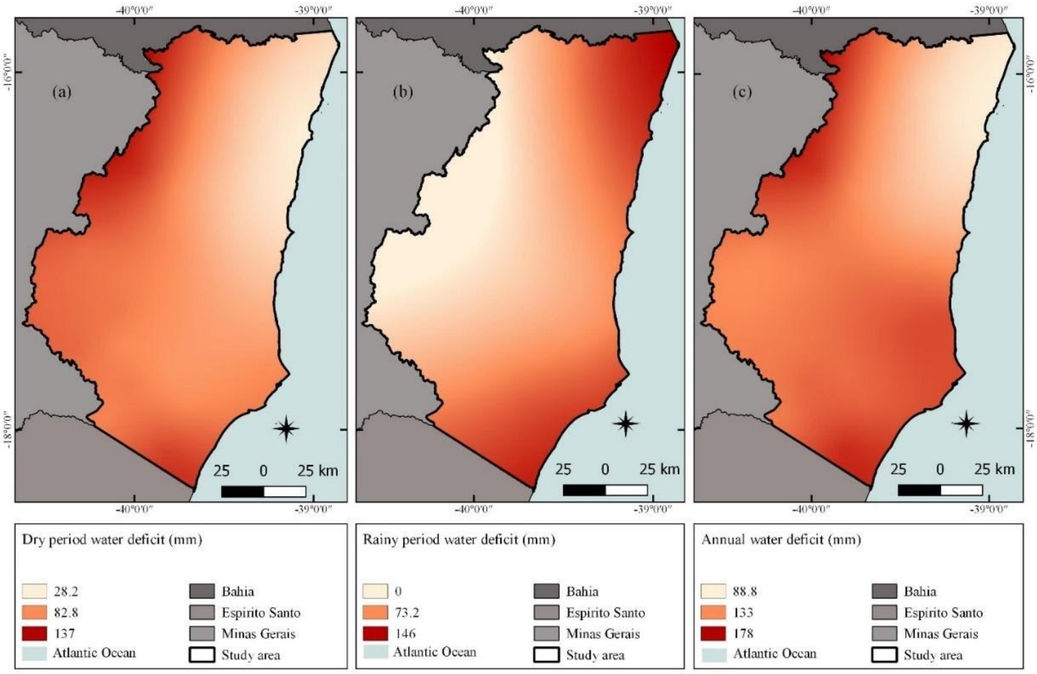
The highest values of annual potential evapotranspiration were observed in the northeast and southeast (Figure 5c). The areas with the highest evapotranspiration are also the areas with the highest rainfall and average annual temperatures above 26 °C. The maximum evaporation rates occur in December and January, obtaining 1,500 mm/year of evapotranspiration in the coastal zone.

The municipalities with the highest evapotranspiration were Belmonte, Mucuri, Nova Viçosa, Caravelas, Alcobaça and east of Santa Cruz Cabrália, municipalities that also coincide with the highest values of spatial distribution of precipitation. Both municipalities are in the coastal zone.

The lowest evapotranspiration values are in the west of the study area, represented by the municipalities of Guaratinga, Jucuruçu, Itanhém, north of Medeiros Neto, west of Vereda, Itabela and Itamaraju, both located in the vicinity of the state of Minas Gerais, with values of 1,131 mm/annual.

The water deficit for the dry, rainy and annual periods is shown in Figure 6. Whose municipalities of Mucuri, west of Itapebi, Itagimirim, Eunápolis and Guaratinga presented the highest water deficits in the dry season (Figure 6a). In the rainy season, Mucuri, Nova Viçosa, Caravelas, east of Belmonte, Santa Cruz Cabrália and Porto Seguro account for the greatest water deficits (Figure 6b). The greatest deficit occurred in the rainy season, which although the highest precipitation values occur, also present the highest temperatures in the year.

Figure 6 - Water deficit on the Discovery Coast and The Extreme South of Bahia. (a) water deficit in the dry period (April to September). (b) water deficit rainy season (October to March). (c) annual water deficit.



Source: Elaborated by the authors (2020)

It was found that the annual water deficit (Figure 6c) presented values from 88.8 to 178 mm. The maximum values of water deficit are observed in the south and northwest of the area, coincident with the municipalities of Mucuri, west of Itapebi, Itagimirim and Guaratinga, both bordering the State of Minas Gerais and Espírito Santo and with maximum evapotranspiration. The smallest water deficit was found in the northeast of the studied area, comprising the municipalities of Belmonte, Santa Cruz Cabrália, Porto Seguro, Itabela, east of Eunápolis and Itapebi and north of Prado and Itamaraju and corroborate as the areas of annual precipitation.

Climate and Soil Relationship

The relationship between climatic, pedological and topographic data (See Figures 2, 3 and 4), indicated that, spatially, low and flat areas with a predominance of Latosols are associated with higher precipitation and higher temperature between April and September, corroborating by Souza et al. (2006), that identified was higher temperatures in lower altitude locations in the Doce river basin, while Maciel, Barcelos and Oliveira (2012) identified a direct and positive relationship between temperature and altitude in the north of Minas Gerais that is close the studied region.

Annually and dry season in the area Northeast has the highest precipitation, while the southeast has the highest temperatures. In both regions, coastal cities predominate with altitudes lesser than 200 meters, flat relief and soils with good drainage and deep characteristics, which may suggest better infiltration into the soil. At the same time, they are characteristics of places with a strong extension of erosive processes, in which the maritime action and oceanic climatological conditions can contribute to greater weathering of these places.

The highest temperature in the Southeast suggests observing the occurrence of land use in this location. Where forestry for pulp and paper production is predominant. It extends over a large territorial area in the extreme south of Bahia, associated with pasture areas to produce cattle and milk. Both activities demand a high level of exploitation of soil and water resources and must have an integrated management process for the use of land and water resources, in compatibility with the demand for water use. Monteiro (2009) also emphasizes the importance of knowing the climatic characteristics for the planning of human activities, including agricultural and forestry production, since the rains happen centralized or even absent in certain periods, being unable to compensate for the water in the soil causing deficiency.

However, higher rates of evapotranspiration are associated with increased slope area and altitude, specifically in the dry and rainy periods while the water deficit follows this trend only in the rainy season. But, Meneses et al. (2009) reinforce the difficult to estimative the evapotranspiration in relation to relief. Profeta et al., (2018) found values were highest of the forest evapotranspiration compared to the no-vegetation cover, but not significant relationship with the relief and Meneses et al. (2019) overestimated the values for the mountainous relief when compared to the flat relief conditions.

Annually, the highest evapotranspiration rates are associated with areas of higher temperature and the importance of land use management. Cecon and Ramos (1999) emphasize that, development and stress of plants is conditioned to water deficit, and critical values of water availability.

The temperature can indirectly influence evapotranspiration conditions. According to Lemos Filho et al. (2010), temperature, along with relative humidity, solar radiation, wind and rain, make up climatic problems that affect the rate of evapotranspiration. The air temperature acts on evapotranspiration, because the solar radiation absorbed by the atmosphere and the heat emitted by the cultivated surface, raise the air temperature (TEIXEIRA; LIMA FILHO, 2004). Such conditions bring the importance of the temperature as a considerable variable in the climatic conditions of the region and can influence the place according to the topographic and pedological aspects, as noted in Ismael Filho (2015) and Alves and Mariano (2016) reported the effect of hypsometry on the evapotranspiration of urban climates. The study developed in the Avacaí basin, Rio Grande do Sul, also confirmed the direct relationship between altitude, temperature and evapotranspiration regulation.

This study sought spatial relationships between climatic aspects in the coastal region of southern Bahia and the importance of spatial locations with greater water availability in the atmosphere and in the soil, showed the highlights that the climate is the determining factor in the formation and affect the characteristics of soil (BECKER; BURIOL; STRECK, 2013; PEREIRA et al., 2019; RUBIRA et al., 2019) and the topographic determines the existence of climatic gradients in a locality and may favor greater soil water availability.

CONCLUSION

The months of October to January have rainfall above 100 mm/month, which is the wettest period. The highest average temperature can reach a maximum of 28.2°C in the rainy season and a minimum of 20.45°C in the dry season. The average annual temperature is between 22°C in the west and 26°C in the southeast of the south coast. Areas with higher annual evapotranspiration are similar to places with higher rainfall and average annual temperatures. The maximum evapotranspiration rates occur in December and January, and the municipalities of Belmonte, Mucuri, Nova Viçosa, Caravelas, Alcobaça and Santa Cruz Cabrália respond with 1,500 mm/year of evapotranspiration.

The water deficit in the dry and rainy season is well delimited, to the west and east, respectively. The area has 92.6% elevation up to 320 m and the relief is predominantly flat to wavy, representing 80.2% of the area. The predominant pedology is the Dystrophic Yellow Latosol, Dystrophic Yellow Argisol, and dystrophic Red-Yellow Latosol.

In summary, the northeast and southeast regions present higher rainfall in the year, as well as the highest annual temperatures, with this, evapotranspiration is also higher. The largest water deficit was in the southern region of the area and in the west region, characterized by lower rainfall. The supply of precipitation is reduced in these places and anthropic activities and the conservation of natural resources consider adequate planning for the demands and support capacity of the ecosystem.

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