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Soil/Phytofisionomy Relationship in Southeast of Chapada Diamantina, Bahia, Brazil

Marcelo Araujo da Nóbrega, Ariel Moura Vilas Boas

Abstract**—**This study aims to characterize the physicochemical aspects of the soils of southeastern Chapada Diamantina - Bahia related to the phytophysiognomies of this area, rupestrian field, small savanna (savanna fields), small dense savanna (savanna fields), savanna (Cerrado), dry thorny forest (Caatinga), dry thorny forest/savanna, scrub (Carrasco - ecotone), forest island (seasonal semi-deciduous forest - Capão) and seasonal semi-deciduous forest. To achieve the research objective, soil samples were collected in each plant formation and analyzed in the soil laboratory of ESALQ - USP in order to identify soil fertility through the determination of pH, organic matter, phosphorus, potassium, calcium, magnesium, potential acidity, sum of bases, cation exchange capacity and base saturation. The composition of soil particles was also checked; that is, the texture, step made in the terrestrial ecosystems laboratory of the Department of Ecology of USP and in the soil laboratory of ESALQ. Another important factor also studied was to show the variations in the vegetation cover in the region as a function of soil moisture in the different existing physiographic environments. Another study carried out was a comparison between the average soil moisture data with precipitation data from three locations with very different phytophysiognomies. The soils found in this part of Bahia can be classified into 5 classes, with a predominance of oxisols. All of these classes have a great diversity of physical and chemical properties, as can be seen in photographs and in particle size and fertility analyzes. The deepest soils are located in the Central Pediplano of Chapada Diamantina where the dirty field, the clean field, the executioner and the semideciduous seasonal forest (Capão) are located, and the shallower soils were found in the rupestrian field, dry thorny forest, and savanna fields, the latter located on a hillside. As for the variations in water in the region's soil, the data indicate that there were large spatial variations in humidity in both the rainy and dry periods.

Keywords**—**Bahia, Chapada diamantina, phytophysiognomies, soils.

I. Introduction

THE north of Espinhaço is formed by several mountainous alignments called Diamantina-Espinhaço, extensions of the Espinhaço Chain, in the State of Bahia (Fig. 1). It is an extensive area of approximately 60,000 km² and mainly covers the central portion of the State of Bahia and stretches to the north, south and west of this State, between coordinates around 10° to 15° S and 40° to 44° W. The plateaus and mountains of the Espinhaço proper and the Chapada Diamantina are normally considered as the north of the Espinhaço Chain and the Chapada Diamantina covered with metasedimentary rocks inserted in folded and failed structures, dating from the Middle and Upper Proterozoic [3], [5], [8], [9]. Four geographical microregions integrate this region: Chapada Diamantina Setentrional, Chapada Diamantina Meridional, Baixo-Médio São Francisco and Serra Geral da Bahia.

The dominant climate is the sub-hot and semi-humid tropical of the tropical zone of Central Brazil [7]. The average annual temperature ranges from 19 to 20 °C and the average in winter is below 18 °C. The temperature can drop below 10 °C on the coldest days of winter in some points above 1,000 m. Precipitation in this region varies between 500 and 1,300 mm annually and depends on several factors. The rains occur mainly between November to March and often have a torrential character. Orographic rains also frequently occur in the eastern sector of Chapada Diamantina, in the Ranger Mountain Sincorá and in the Ranger Mountain of Tombador, a factor that favors the increase in precipitation in these places, staying above 1,200 mm for the locations of Lençóis, Andaraí and Ibicoara.

The hydrographic network in the north of chain of Espinhaço belongs to 5 large basins: the São Francisco River, to the west and north; that of River of Contas and River Pardo, both in the south; that of River Paraguaçu and Itapicuru, both to the east. Usually, large and medium rivers are perennial due to the nature of the area's lithology.

The geological history of the Espinhaço Chain begins in the Middle Precambrian when the sedimentation of the Supergroup Espinhaço sequences begins [5]. Its rocks are metamorphic or sedimentary. In the Plateau of Espinhaço, pure quartzite rocks, feldspatic and sericitic quartzites, feldspatic sandstones, pelites and metavolcanic rocks are predominant. In Chapada Diamantina or Planalto da Diamantina clayey sandstones, ortho-quartzite sandstones, siltites, claystones and conglomerate lenses occur more frequently.

Geomorphologically, the Espinhaço Plateau and the Diamantina Plateau are divided into smaller units. The Espinhaço Plateau is made up of three units which are: Northern Sierras, Central Sierras and Surface of the Generals, and the Diamantina Plateau, is subdivided into Northern Plateau Blocks, Chapadas de Morro do Chapéu, Central Pediplano, Serra da Borda Ocidental and Eastern slopes. In this study the topographic section to show the relationship between phytophysiognomies and soils is inserted in the Central Pediplano, in the Serras da Borda Oriental (Serra do Sincorá) and nearby (Fig. 2).

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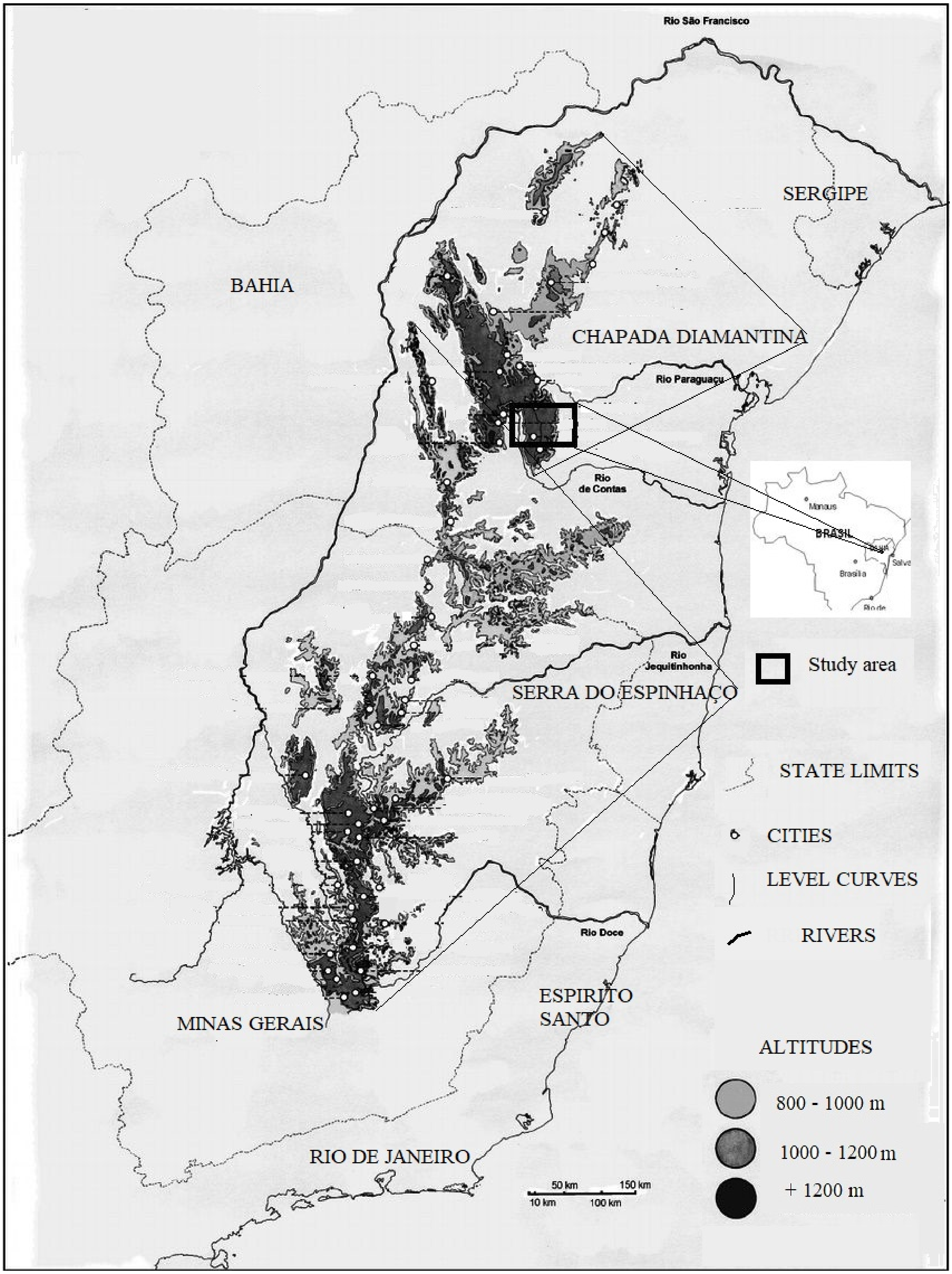

Fig. 1 North Espinhaço Chain. Eastern Brazil in the State of Bahia

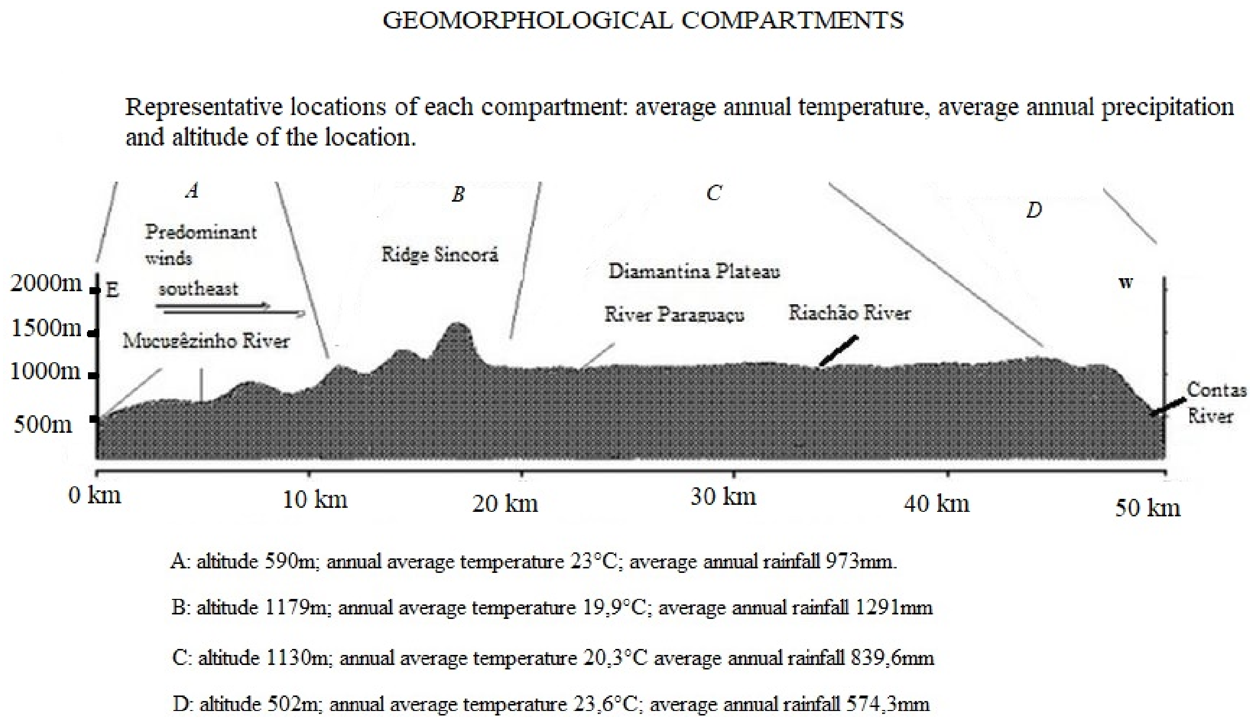

Fig. 2 Topographic profile of part of Chapada Diamantina corresponding to the study area. The figure also shows the ombrothermal graphs of each sector of the profile [7]

A true mosaic of soils occurs in the north of the Espinhaço Chain, from deep ones, such as oxisols, to the shallower ones, such as litholic soils (entisols) that predominate in areas with mountainous relief. According to an exploratory survey of soils carried out by the RADAMBRASIL Project [5], [8], [9], there are several classes of soils in this region, among them are alicos and dystrophic red-yellow oxisols, dark red eutrophic latosol, eutrophic red-yellow podzolic, acidic and dystrophic (ultisols), eutrophic cambisol, dystrophic and eutrophic litholic soils, hydromorphic podzol (spodosolos), vertisols, sands dystrophic quartzose (enthesols) and dystrophic and eutrophic alluvial soils (enthesols). Regarding fertility, they vary, but acidic and not very fertile soils predominate.

A wide variety of vegetation types are found in Chapada Diamantina and Planalto do Espinhaço, partly the result of their dissected relief with different levels of altitude and slope orientations, which sometimes favor orographic rains and sometimes make it difficult for rains to occur. According to the vegetation map of Brazil on a scale of 1:5,000,000 [10], in this area, there are several types of vegetation: semideciduous montane forest in the east of Chapada Diamantina, on the wetter slopes of the Sincorá mountain range and in the Tombador mountain range; seasonal deciduous montane forest in the Ranger Mountain of Garapa and in the Serra de Caetité, in Espinhaço; savanna-stepp forested and wooded (caatinga arboreal and arbustiva-arbórea) in the northern end of Chapada Diamantina, in the Northern Planaltic Blocks and in sections of the Saw da Borda Ocidental and also in some of the Espinhaço mountains, arranged in patches; wooded savannas in several stretches of the Chapada Diamantina, in the Sincorá mountain range, in the Serra da Borda Ocidental, in the Morro do Chapéu region and in the Northern Planaltic Blocks, and also in Espinhaço, in the Garapa mountain range, Serra do Monte Alto, Caetité mountain range and in the Macaúbas mountain range; grassy-woody savanna, mainly in the Central Pediplano of Chapada Diamantina; montane ecological refuge (rupestrian fields) in the mountains usually over 1,000m in Chapada Diamantina, especially in the Sincorá mountains and in the Serra da Borda Ocidental; a variety of ecotonal types, such as savanna/seasonal forest in the Espinhaço mountains and between savanna-stepp/seasonal forest in the north-central sector of Chapada Diamantina (Figs. 2 and 3).

As for the Chapada Diamantina framework with regard to the Brazilian morphoclimatic and phytogeographic domains according to [1], it presents particularities of three domains: the domain of semi-arid interplanaltic depressions, the seas of forested hills and the dominion of the plateaus covered by savannahs. It is an area of enclaves and transition, where the surroundings are almost entirely occupied by the domain of semi-arid interplanaltic depressions. As for the Chapada Diamantina framework with regard to the Brazilian morphoclimatic and phytogeographic domains according to [1], it presents particularities of three domains: the domain of semi-arid interplanaltic depressions, the seas of forested hills and the dominion of the plateaus covered by savannahs. It is an area of enclaves and transition, where the surroundings are almost entirely occupied by the domain of semi-arid interplanaltic depressions. In this study, we comment that some of these contact areas are the result of complex gradual transitions, such as, for example, the transition between

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Atlantic forest/Thorny Dry Forest/Savanna or, are the result, of sudden passages made by orographic and lithological accidents, such as Chapada Diamantina. The presence of the cerrado and semideciduous forests here is called by the author “islands of vegetation” and can only be explained by the existence of exceptional factors in the regional context of lithological, microclimate, hydrological, topographic and paleobotanical order.

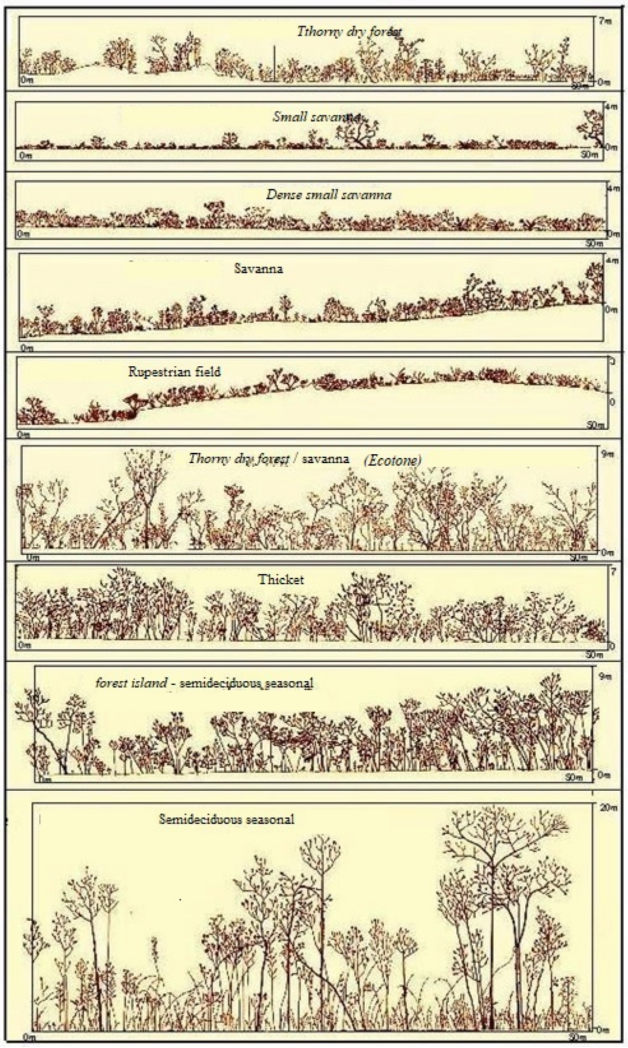

Fig. 3 Phytophysiognomies of the study area [7]

Because it has geomorphological sites of great beauty and also to preserve its biodiversity, the Chapada Diamantina National Park was created on September 17, 1985. It has an area of 1,520 km² and occupies more than half of the Sincorá mountain range in the Eastern Slopes of Chapada Diamantina. It is one of the most beautiful areas of Chapada Diamantina, with large canyons and waterfalls, such as the gorge of the Paraguaçu River and the Rio Preto with unevennesses that reaches more than 400 m and the Fumaça waterfall, considered one of the highest in the world. It has elevations almost always above 1,000 m with peaks exceeding 1,700 m, sometimes presenting immense walls of metasedimentary rocks. The dominant vegetation is that of a rupestrian field with many endemic species and, considered by many botanists, as an area of great biodiversity.

The objective of this article is to present a study of the soils of the southeastern Chapada Diamantina located in the state of Bahia associated with the phytophysiognomies present in this location, since the soils have a close relationship with the types of vegetation, their size and density, and the occurrence and frequency of certain species.

II. Methodology

Another study carried out was that of soils, due to the close relationship between them and the types of vegetation, their size and density and the occurrence and frequency of certain species. For this, soil samples were collected in each plant formation and analyzed in the soil laboratory of ESALQ - USP. The analyses consisted of the physical and chemical characteristics of the collected soils. Soil collections for chemical analysis purposes were made for each type of phytophysiognomy in the plots where the vegetation profiles were made. In each 50 x 4 m plot, collections were carried out at 9 different points, three at one end of the plot, three at the other end and three in the middle of the plot. For each of these points, the samples were also collected at three different depths, one at the level of the superficial horizon, another at a depth of 25 cm and the other at a depth of 50 cm. There have been cases of soils that were not collected at all of these depths due to their low thickness. In some cases where they did not reach 50 cm but reached, for example 40 cm, then it was collected at that depth. Then, in the laboratory, a composition of these samples was made for each depth level (three samples), to then proceed with chemical analyzes. The tables with the results of the samples refer to the average of the three compositions along the plots.

Chemical analyzes included soil fertility determinations, which were: pH ($CaCl_2$), organic matter - MO (g/dm³), assimilable phosphorus - P (mg/dm³), potassium - K (mmolc/dm³), calcium - Ca (mmolc/dm³), magnesium - Mg (mmolc/dm³), potential acidity - H + Al (mmolc/dm³), sum of bases - SB (mmolc/dm³), cation exchange capacity - T (mmolc/dm³) and base saturation - V (%).

For the physical analyses, the composition of the soil particles was verified, that is, the texture. For each plot, samples were taken at two locations in the greatest depth and a composition was made. Regarding the size of the particles, they were separated into two categories: < 2 mm (TFSA) and > 2mm; this step was done in the terrestrial ecosystems laboratory at USP's Ecology Department. Particles smaller than 2 mm were sent to the ESALQ Laboratory, University of São Paulo. They consisted of verifying the percentage of total sand, silt and clay, resulting in classes of soil texture. The result shown is the average of the two points of each plot in the different ecosystems. The textural classes according to the ESALQ soil laboratory are: up to 14% clay, sandy; 15 to 24%, medium-sandy; 25 to 34%, medium-clayey; 35 to 59%, clayey and; above 60%, very clayey.

Another important factor was also studied to explain the

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variations in the vegetation cover in the region, the variation in soil moisture in the various physiographic environments existing along a topographic profile [10]. The choice of points was based on the types of environments found from east to west in the area under study: on the eastern slope of the Mountain of Sincorá, within the Ranger Mountain do Sincorá, on the eastern slope of the Central Pediplano da Chapada Diamantina, at the top of this pediplano in three points with different phytophysiognomies and, on the west slope of this pediplane, also at three points with different phytophysiognomies. They were made in two periods, in the month of November, rainy and, in the month of July, dry in most ecosystems. Soil collections were made in the plots where the vegetation profiles were made, except for the rupestrian field, where another location with easier access was chosen and also in an area with cultivated vegetation - coffee, where a location corresponding to the eastern slope of the Central Pediplano. The soils were collected on the surface (0-5 cm) in metal cylinders at 5 different points along the plots and, in the case of the coffee area, at points around a 50 m line. The samples were deposited in cans to dry and hermetically closed. In the laboratory, they were weighed and then opened to dry in a Greenhouse until constant weight. Then, they were weighed again and the difference in weight corresponding to humidity was observed.

Another study carried out was a comparison between the average soil moisture data of the seasonal semideciduous forest with the average annual rainfall data from Ibicoara; the soil moisture data of the semideciduous seasonal forest (Capão - Forest island) with the data of precipitation from Cascável; the caatinga (Thorny Dry Forest) soil moisture data with the Jussiape precipitation data. It was done this way, because these localities correspond to the defined phytophysiognomic types [2], [6].

III. Results and Discussion

As mentioned in the physiographic characterization of the region, the soils found in this part of Bahia can be classified into 5 classes, with oxisols predominating. All of these soil classes have a great diversity of physical and chemical properties, as can be seen in the photographs (Figs. 3 and 4) and in the granulometry (Fig. 4 and Table I) and fertility analyzes made for them (Tables II and III). The depth of the studied soils varied widely, from the deepest around 1.5 to 2 m, to the least deep, approximately 5 to 10 cm. The deepest are located in the Central Pediplano of Chapada Diamantina, where the dirty field, the clean field, the Carrasco and the semideciduous seasonal forest (capão) are located. According to studies carried out in this area, it was found that they have an average depth of 1.60 m [9]. It also verified the presence of many aggregates, composed of sands and clays in the different studied depths. The shallower soils found were those of the rupestrian field, the caatinga, and the cerrado field, the latter located on a hillside. In these places they were at most 50 cm deep and with a lot of gravel and pebbles.

Fig. 4 (a) Partial soil profiles under Thorny Dry Forest vegetation, (b) Areat between Thorny Dry Forest and Savanna, (c) Carrasco (Thicket) and (d) semideciduous seasonal forest - Southeast of Chapada Diamantina, Bahia

Regarding textural classes, they range from sandy, through intermediate classes, to clayey (Table I). The rupestrian field was the one with the highest amount of sand (sandy class), followed by the caatinga (thorny dry forest), the savanna field and the dry forest between the caatinga-Savanna (ecotone) within the middle-sandy class. The soils under semideciduous seasonal forests, on the other hand, presented a greater amount of clay (26%) falling into a class of medium-clay texture. Finally, the soils in the executioner, in the clean field and in the dirty field were the ones that presented the greatest amount of clay (≅ 40 to 45%) falling into a clay class. These last phytophysiognomies are found in the same geomorphological unit dominated by detrital coverings of the Tertiary (Central Pediplane). According to [9] and [5], the soils of the Central Pediplane of Chapada Diamantina vary from a clayey to medium-clayey texture, and those of the Sincorá mountain range, from a sandy to medium-sandy texture. These data are in agreement with the results obtained in this research.

The color observed in most soils in the clean field, in the dirty field and in the executioner, varies from yellow to red, which indicates different contents of iron and aluminum oxides [4]. The soils of the rupestrian field, on the other hand, have a dark brown surface due to the high concentration of organic matter on sandstone and quartzite. The soils in the caatinga, in the Thorny Dry Forest (caatinga)/savanna

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(ecotone) and in the savanna field are lighter in color, predominating light-gray-yellow. In the savanna field, on the surface, they were darker because of the greater presence of organic matter. In seasonal forests, they have a greater color variation in their profile, ranging from dark reddish-brown on the surface to yellow-red at a depth of 50 cm.

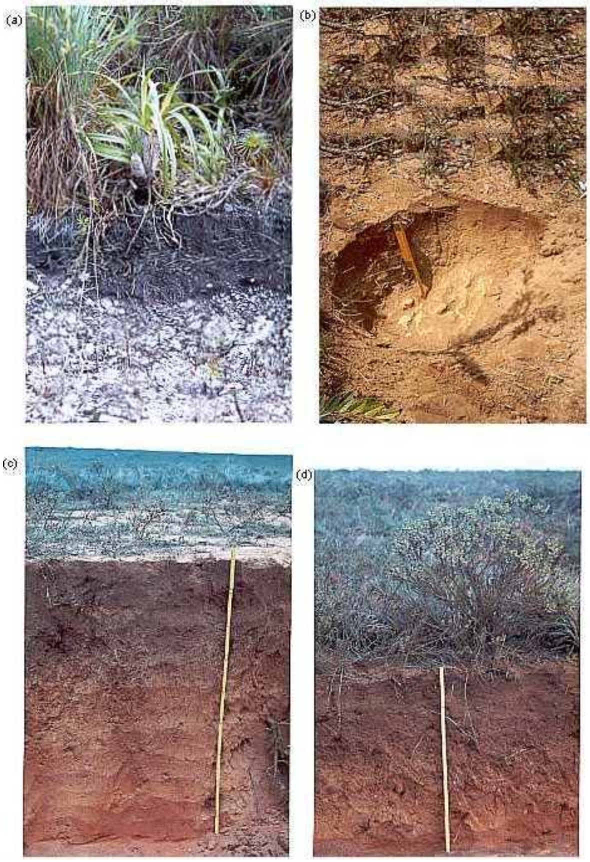

Fig. 5 (a) Partial soil profiles under rupestrian field vegetation, (b) Savanna field, (c) clean field and (d) dirty field - Southeast of Chapada Diamantina, Bahia

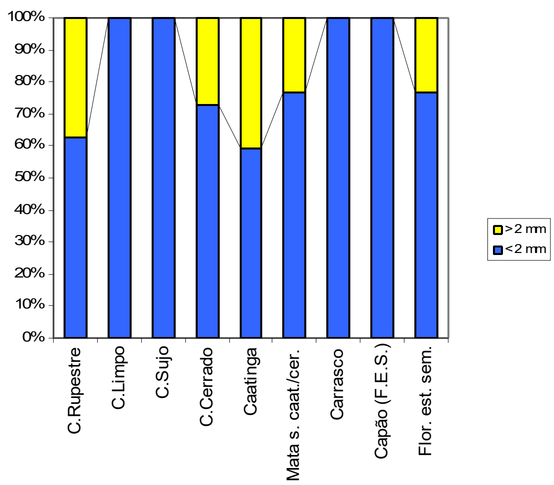

Fig. 6 Percentage of fragments larger and smaller than 2 mm from the studied soils. Southeast of Chapada Diamantina, Bahia

TABLE I
TEXTURAL CLASSES OF SOILS IN THE SOUTHEAST OF CHAPADA DIAMANTINA - BAHIA

Phytophysionomy	Texture Classes
Rupestrian field	Sandy
Small savanna	Clayey
Dense small savanna	Clayey
Savanna	Medium-sandy
Tthorny dry forest	Medium-sandy
Thorny dry forest / savanna	Medium-sandy
Thicket (Carrasco)	Clayey
Capão (*forest island* - semideciduous seasonal forest)	Medium-clayey
Semideciduous seasonal forest	Medium-clayey

Regarding the variations of water in the soil in the region over a longitudinal cut or topographic profile, the data indicate that there were large spatial variations in humidity and, also, over the months considered, in some ecosystems. November is one of the wettest in general throughout the region and the month of July, one of the driest in most environments, as can be seen in Tables II and III and in Figs. 7 and 8.

TABLE II
SOIL MOISTURE IN JULY IN SOUTHEAST OF CHAPADA DIAMANTINA – BAHIA

Environment	Samples (% Moisture)					MEDIUM	D.P.
	1	2	3	4	5		
Thorny dry forest (caat.)	0,12	0,24	0,48	0,13	0,20	0,234	0,146
Thorny. *Dry Forest/Savanna*.	3,00	2,83	2,11	0,82	1,33	2,018	0,941
Dense small savanna	2,75	2,90	2,34	2,26	2,72	2,594	0,278
Small savanna	4,49	5,25	7,76	10,5	8,21	7,242	2,417
Carrasco (Thicket)	9,56	8,42	8,87	12,13	9,46	9,688	1,441
Capão (semideciduous seasonal forest)	8,67	7,58	9,22	7,85	7,54	8,172	0,742
Coffe	8,98	9,11	9,14	9,02	7,18	8,686	0,844
Rupestrian field	13,06	23,72	24,18	21,42	24,10	21,296	4,741
Semideciduous seasonal forest	23,05	21,39	24,13	17,04	19,19	20,960	2,877

TABLE III
SOIL MOISTURE IN NOVEMBER IN SOUTHEAST OF CHAPADA DIAMANTINA – BAHIA

Environment	Sample (% Moisture)					MEDIUM	D.P.
	1	2	3	4	5		
Thorny dry forest	0,78	1,29	3,77	2,40	2,50	2,148	1,165
Thorny.Dry Forest/Savanna.	6,12	6,76	5,00	3,19	10,51	6,316	2,708
Dense small savanna	4,48	3,93	4,13	5,65	3,16	4,270	0,910
Small savanna	11,04	11,00	11,45	10,56	11,88	11,186	0,500
Carrasco (Thicket)	9,99	7,24	13,77	7,78	12,04	10,164	2,772
Capão (semideciduous seasonal forest)	10,56	10,93	9,91	11,79	12,22	11,082	0,931
Coffe	8,77	7,74	8,27	6,06	7,76	7,720	1,020
Rupestrian field	17,64	20,08	30,51	18,52	17,08	20,766	5,564
Semideciduous seasonal forest	19,91	18,61	24,66	21,47	16,67	20,264	3,023

The greatest contrasts of moisture observed between the considered months were verified in the caatinga and in the dry forest between the caatinga/cerrado, being more than double between July and November. These locations are to the west

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of the study area, in a "rain shadow" area. This is in accordance with the ombrothermal diagram of Jussiape, which shows that the region of the valley of the River of Contas has a well-defined dry period and this occurs mainly in winter. On the other hand, the smallest contrasts were found in the rupestrian field, in the semideciduous seasonal forest and in an area with coffee, in the Ranger Mountain of Sincorá and on the eastern slope of the Central Pediplano. In these places there is no dry period, as shown in the ombrothermic graph of Ibicoara. Intermediate data, between the valley of the Contas River and the Serra do Sincorá, can be seen in the capon of semideciduous seasonal forest, in the grassy-woody savannas and in the Carrasco, both places at the top of the Central Pediplano of Chapada Diamantina. These are locations that correspond to the Cascavel ombrothermic graph.

A fact to note is the soil moisture data of the area with coffee. It was expected that this area had a higher humidity, as it is located on the eastern slope of the Central Pediplane, near Ibicoara. However, as the coffee plantation is a shrubby vegetation, the soil surface was little protected from direct sunlight, favoring greater evaporation.

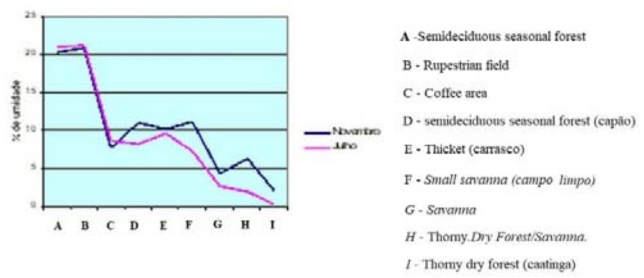

Fig. 7 Difference in soil moisture between July and November in the various ecosystems in the area - Southeast of Chapada Diamantina, Bahia

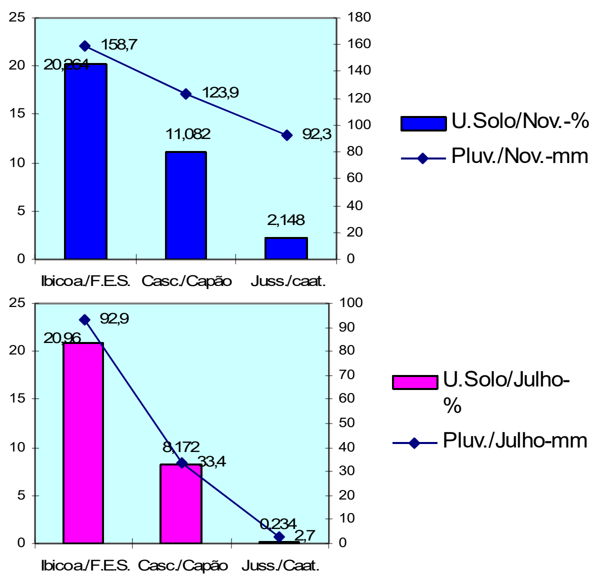

Fig. 8 Comparisons between soil moisture and rainfall: (a) in the month of November; (b) in the month of July. Southeast of Chapada Diamantina - Bahia

In the comparison made, with the data of average soil moisture with those of average annual rainfall, the results show that the greater the precipitation, the greater the soil moisture in the considered regions. Comparisons were made of soil moisture collected in July and November and rainfall data in those same months: soil moisture data from the semideciduous seasonal forest of the Saw Sincorá with that of Ibicoara; the moisture data of the soil of the semi-deciduous seasonal forest capon of the Central Pediplano with the rainfall of Cascavel and the moisture data of the caatinga soils in the valley of the River of Contas with the rainfall of Jussiape. The correlation coefficients presented were 0.9998017 for November and 0.9988479 for July (Figs. 7 and 8).

TABLE IV
pH, POTENTIAL ACIDITY AND ORGANIC MATTER OF SOILS IN THE SOUTHEAST OF CHAPADA DIAMANTINA - BAHIA

Phytophysionomy	Deph. cm	pH $CaCl_2$	H + Al mmolc/dm³	Organic matter g/dm³
Rupestrian field	0 – 5	2.9	337.0	127.0
	20	2.5	429.0	112.0
Small savanna	0 – 5	4.1	50.3	30.3
	25	4.0	53.7	25.7
	50	4.0	41.0	20.7
Dense small savanna	0 – 5	3.6	180.0	61.3
	25	3.7	135.3	41.7
	50	3.8	94.7	29.7
Savanna (cerrado)	0 –5	4.0	62.3	41.0
	25	3.8	47.3	23.0
	35	3.9	29.5	18.0
Thorny Dry Forest (caatinga)	0 – 5	4.9	17.7	23.3
	25	4.0	28.0	17.0
	50	4.0	28.0	14.0
Thorny dry Forest /Savanna	0 – 5	3.7	80.0	47.7
	25	3.4	67.3	25.0
	50	3.5	44.0	18.0
Carrasco (Thicket)	0 – 5	3.6	130.0	61.3
	25	3.7	89.3	34.3
	50	3.8	56.0	20.7
Capão (Semideciduous seasonal Forest)	0 – 5	3.1	297.0	116.0
	25	3.3	179.0	55.6
	50	3.7	118.0	32.3
Semideciduous seasonal forest	0 – 5	3.5	180.0	69.0
	25	3.9	89.7	33.7
	50	3.9	80.0	24.3

As for the pH, they are mostly strongly acidic, mainly the soil of the rupestrian field that presented a pH of 2.9 on the surface, followed by soils from the seasonal semideciduous forest (capão) in the Central Pediplano and that of the semideciduous seasonal forest on the eastern slope of the Sincorá mountain range (Table IV). In the caatinga they showed less acid reaching the surface at a value of 4.9, followed by a clean field with 4.1. There were no greater differences in pH from one horizon to another, as can be seen in Table IV. The average acidity range of almost all collected soils was between 3.5 and 4.0 pH, therefore very acidic. As for acidity (H + Al), soils are also more acidic in phytophysiognomies where there is a greater amount of rainfall, that is, the rupestrian field and the areas with seasonal

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semi-deciduous forests submitted to rainfall above 1,000 mm. In areas with less precipitation, this acidity is much lower, as shown by data from the caatinga, dry forest between caatinga-cerrado, clear field and cerrado fields. This is in agreement with [3], that acidic soils are more common in regions where it rains a lot, removing, by continuous leaching, the exchangeable bases of the colloidal complex of the upper horizons and leaving hydrogen ions in replacement. In dry regions, where rainfall is low, the opposite occurs, with little loss or even accumulation of calcium, magnesium, potassium and sodium carbonate salts, which saturate the colloidal complex and result in alkaline soils. Table IV also shows a decrease in the values of this acidity as the soil becomes deeper, except for the rupestrian, caatinga and clean fields, which show their highest values on the horizon around 25 cm.

The organic matter of the studied soils also varied a lot from one phytophysiognomy to another, as shown in Table IV. The rupestrian field and seasonal forests had the highest values of organic matter, followed by the Carrasco and the dirty field with similar values. The caatinga and the clear field showed the lowest values. It is also observed that the concentration of organic matter decreases a lot with the depth, being more than double, from the surface up to 50 cm.

TABLE V
PHOSPHORUS (P), POTASSIUM (K), CALCIUM (CA) IN THE SOILS OF SOUTHEASTERN CHAPADA DIAMANTINA - BAHIA

Phytophysionomy	Deth. Cm	P 8G/dm^3	K mmolc/dm^3	Ca mmolc/dm^3
Rupestrian field	0 – 5	23.0	2.5	9.6
	20	22.0	1.4	1.0
Small savanna	0 – 5	5.0	1.1	4.3
	25	3.7	0.5	2.7
	50	2.3	0.2	1.7
Dense small savanna	0 – 5	6.3	0.7	1.3
	25	4.7	0.5	1.0
	50	3.3	0.3	1.0
Savanna(cerrado)	0 –5	5.0	1.5	4.3
	25	4.3	0.8	1.0
	35	3.5	0.7	1.5
Thorny Dry Forest(caatinga)	0 – 5	5.7	3.2	21.7
	25	4.0	2.2	9.3
	50	4.0	1.9	5.0
Thorny dry Forest /Savanna	0 – 5	5.3	3.3	7.0
	25	3.7	1.8	4.3
	50	3.0	1.1	1.3
Carrasco (Thicket)	0 – 5	6.3	1.3	7.0
	25	4.3	0.6	1.7
	50	2.7	0.2	1.0
Capão (Semideciduous seasonal Forest)	0 – 5	14.0	1.6	5.0
	25	7.7	1.0	2.7
	50	4.3	0.5	1.7
Semideciduous seasonal forest	0 – 5	9.7	2.2	8.0
	25	4.7	0.9	1.7
	50	3.7	0.6	1.7

The contents of soil macronutrients in the different phytophysiognomies also varied a lot as shown in Tables V end VI. Phosphorus (P) showed its highest indexes in the rupestrian field and in semideciduous seasonal forests with results considered medium and low (between 7 to 40 mg/dm^3). In all other soils, the phosphorus contents were very low (below 6), mainly the soils of the clean and cerrado fields. Potassium (K) had values considered high (above 0.60 mmolc/dm^3) in most ecosystems, mainly in the caatinga and in the caatinga/cerrado ecotone (dry forest). The lowest potassium values were observed in the clean and dirty fields. Calcium (Ca) showed the best values in the caatinga and in the caatinga/cerrado ecotone and the worst in the dirty and cerrado fields. As for magnesium (Mg), it presents levels considered good (above 0.8 mmolc/dm^3) in all phytophysiognomies [3], [4], mainly in the caatinga. The lowest values of this macronutrient remained with the dirty field. The data in the table also inform that there is a decrease in the values of all these macronutrients as the depth of the soil increases.

TABLE VI
MAGNESIUM (MG), SUM OF BASES (SB), CATION EXCHANGE CAPACITY (T) AND BASE SATURATION (V) OF THE SOILS OF SOUTHEASTERN CHAPADA DIAMANTINA - BAHIA

Phytophysionom	Deth. Cm	Mg mmloc/dm^3	SB mmolc/dm^3	T mmolc/dm^3	V %
Rupestrian field	0 – 5	7.3	19.5	356.5	6.6
	20	2.0	4.4	433.4	1.0
Small savanna	0 – 5	3.3	8.8	59.1	14.7
Dense small savanna	25	2.3	5.8	59.5	9.7
	50	1.7	3.6	44.6	8.3
Savanna (cerrado)	0 – 5	1.3	4.1	184.1	2.3
	25	1.0	2.5	137.8	2.0
	50	1.0	2.3	96.9	2.0
Thorny Dry Forest (caatinga)	0 –5	3.3	9.2	71.5	15.3
	25	1.0	2.8	50.2	6.3
	35	1.0	3.2	32.7	9.5
Thorny dry	0 – 5	9.3	34.2	51.8	66.0
	25	4.3	15.9	43.9	33.7
	50	2.0	8.9	36.9	24.0
Forest /Savanna	0 – 5	3.3	13.6	93.6	14.7
	25	2.3	11.1	75.8	10.7
	50	1.0	3.4	47.4	7.3
Carrasco (Thicket)	0 – 5	5.0	13.3	143.6	9.0
	25	1.7	3.9	93.2	4.0
	50	1.0	2.2	58.2	4.0
Capão (Semideciduous seasonal Forest)	0 – 5	6.5	13.1	310.1	4.0
	25	3.0	6.7	185.4	3.7
	50	1.7	3.8	121.8	3.0
Semideciduous seasonal forest	0 – 5	6.0	16.2	196.2	8.3
	25	1.3	3.9	93.6	4.3
	50	1.7	4.3	84.3	5.3

Observing Table VI, it can be seen that the soils that presented the highest base values (SB) are those of Dry Spiny Forest (caatinga) and Dry Spiny Forest/Savanna (ecotone), while the lowest values are in the fields savanna (types of cerrado), with close values. In relation to the cation exchange capacity (T or CTC), thesoils with the greatest capacity for this exchange are those in the rupestrian field and in the semideciduous seasonal forest, and the smallest in the driest environments such as the caatinga, for example. The high cation exchange capacity of the soils of the rupestrian field is due to the high content of organic matter present in them

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(Table VI), since the clay is not very expressive in these soils. The base saturation value (V) is used to measure both the acidity and fertility of a soil, in addition to the friability, dispersion and flocculation of clays and their influence on the availability of Ca, Mg and K to plants. The lower the value of V%, the more acid, therefore, with less bases and more H and Al and, therefore, less fertile [4] the soil is. Therefore, it is clear from Table VI that the most fertile soils are in the caatinga (dry thorny forest) and in the ecotone (savanna/dry thorny forest), and the least fertile are in the dirty cerrado field (small dense savannah), seasonal semi-deciduous forests, and rupestrian field. This shows that there is a coincidence between drier climates and more fertile soils in the study area. Also, it is observed that, in general, the higher the value of H and Al, the lower the value of V%. This value in V% decreases progressively as the soil deepens in almost all ecosystems.

Silva et al. [9], near Guinea, municipality of Mucugê (Pediplano Central), indicate a value for base saturation of approximately 27%, therefore higher compared to the soil data for this same geomorphological unit in this study. The average values for base saturation found in the area ranged from 2.2 to 11%, depending on the location. Maybe one of the causes of this considerable difference is the precipitations that are distinct. In the Guinea region, rainfall is lower, around 600 mm, while in the study area, it is around 800 mm. A study of acidic lolic soils done for a place close to Barra da Estiva [9] shows that the saturation in bases of that soil was 7%, being in accordance with the value found in the study area, equivalent in the Serra do Sincorá (6.6%).

IV. Conclusion

The region's phytophysiognomic heterogeneity in a relatively small space is a consequence of sudden changes in topographic and lithological factors, resulting in different types of soil and in different areas in terms of precipitation and temperature.

The soils of the rupestrian fields are very shallow and very acidic, being the most shallow and acidic in the region, the occurrence of this phytophysiognomy seems to be mainly related to the type of litolic soil, shallow and the altitude above 1,000 m.

The occurrence of seasonal semideciduous forests is mainly conditioned by the water factor, either because of rainfall above 1,000 mm, or in the case of forest capons in the Central Pediplano, because of the water in the soil. It has been shown that the soils in these areas are very acidic and have low base saturation, that is, the soils are poor in terms of fertility.

The soils of the dirty field were the poorest found in the region, while the soils of the clean field and the savanna field are slightly more fertile and very similar in chemical composition.

As for the caatinga, the soils were the ones that presented the best fertility conditions, however, as for the physical characteristics; they are very shallow and stony. They are the only soils in the region derived from magmatic rocks.

The ecotonal types of vegetation, dry forest between the caatinga and the cerrado and the carrasco, present poor soils in terms of fertility.

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