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ZONING THE PHYSICAL ENVIRONMENT AS A SUBSIDY TO THE MANAGEMENT AND SPATIAL PLANNING IN AMAZONIAN CONSERVATION UNITS AND SURROUNDINGS - THE CASE OF THE JAMARI NATIONAL FOREST

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ABSTRACT

The current rates of population growth impose on society the increasingly rationaliseduse of spaces. In this sense, the use of zoning can help the understanding of socio-economic and environmental dynamics that would orient the use and occupation of spaces, identifying relationships and impacts on capacity and agricultural aptitude, as well as subsidisingthe implementation of spatial planning policies. The objective of this work was to develop a zoning proposal aimed at making the productive and conservationist aspects from the physical environment properties compatible to the Amazon conservation units and surroundings using as a case study the area of the Jamari National Forest. Environmental zones were compartmentalisedby crossing geological and geomorphological information that resulted in factors and properties that allowed the identification of homologous units in the landscape.The methods used to delimit the environmental zones were interpretation, processing and analysis of images validated in the fieldwork, determination of granulometric and mineralogical values, and petrographic analyses. The results showed, in the proposed scale, the existence of five homologous environmental zones represented on a map under the names ofJacundá, Itapuã, Nascente, LateritaandCujubim zones. The method proved to be effective in evidencing environmental differences in relatively large areas, such as the Amazon conservation areas, making it possible to identify characteristics of the physical environment that allow the orientation between society and nature in order to maintain and improve the conditions of use of natural resources in rural properties located around the Amazon conservation units.

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INTRODUCTION

Over the past 100 years, world population and consumption levels have grown at a considerable pace (Pimentel et al., 1999). By the year 2050, the world population will reach approximately 12 billion people, if the current growth rate of 1.4% per year is maintained (Cohen, 1995; Pimentel et al., 1999). An increase in food production is expected to feed this growing number of people (Fao, 2009). However, as the inhabitants multiply, thousands of hectares of arable land are lost every year due to inadequate management (Pimentel & Kounang, 1998; Pimentel &Pimentel, 2003), such as the negligence with the capacity of the environments or agricultural aptitude, leading to the exhaustion of resources(Ramalho Filho & Pereira, 1999). Thus, studies focusing on natural resources management and human interventions are needed to determine the acceptable rates of resource extraction without the degradation of the ecosystems, to identify sites with distinct aptitudes or to determine what measures should be taken to allow maximum extraction without degradation (Valladares et al., 2011).

For this, it is necessary to know a given environment and its operation (Tricart, 1977). The efficiency of the environmental management of a territory depends largely on surveys and previous systematic studies on the main elements and conditioners of the physical environment (Jiménez-Rueda et al., 1993; Ohara et al.,1996, 2003; Santos et al., 2007).It is also important to know its limits, aptitudes, strategically plan where the fixed ones will be placed, not only as a way tominimise positive impacts (Drew, 1986), but mainly to spatially arrange ways for the flows to circulate and allow the structures to fulfil their functions (Santos, 2008). One of the socially developed ways to understand the environment (the society, included and inseparable) is zoning (Ross, 2009).The compartmentalisation in environmental zones, defined according to the limitations of the physical environment, allows the indication of more sustainable uses for such zones (Shimbo&Jiménez-Rueda, 2007), also allowing to subsidise forms of spatial planning that would orient its use according to the limits and aptitudes of each environment (Bacani&Luchiari, 2014). Zoning allows interdisciplinarity and complex approach (Morin, 2004; Vitte, 2007a; Vitte, 2007b; Morin, 2008) that emphasises not only the analysis of the parts, but the elements integrated and interacting with each other. This approach allows a dialectical attitude between the need for analysis to be adopted, which is inherent to science itself and its methods of investigation, and the need of an overall view on the contrary, which is more relevant to the environment (Tricart, 1977). Studies of this nature with the purpose of minimising impacts on the environment have been carried out throughout the world, although under different perspectives and methods, such as in China (Li &Yeh, 2001) for agricultural purposes and identification of earthquake risk zones (Li et al., 2009), in the Netherlands to identify pollution-sensitive environments in urban areas in order to create control policies (Roo, 1993), in Sub-Saharan Africa to identify agricultural aptitude based on soil fertility (Deckers, 1993). Also in Africa, for the recognition of minerals (Agangiet al., 2013) and in North America as a means tosubsidise development policies based on spatial planning and environment capacity (Rydin, 1998). In Brazil, zoning was recognised as an instrument for management in December of 1974, with the creation of law number 6.151, which approved the 2nd National Development Plan (Brasil, 1974). In it, zoning was proposed with the aim of controlling pollution in cities, bringing with it the need to zone areas for the implantation of industrial parks in urban areas (Ferreira, 2011).

In the early 1980s, the impacts of economic growth on the environment reignited the discussions on sustainability in Brazil. Some methods gained strength in that time, which were the ones that had a systemic approach (Tricart, 1977; Bertrand, 2004), based on the multidisciplinarity of knowledge in order to understand space with the perspective of creating zones. In 1981, the environment became public property. The National Environmental Policy is enacted, law Number 6,938, in August 1981 (Brasil, 1981). Among the instruments for the National Environmental Policy was zoning, until then called "environmental zoning", according to Article 9, II, of the above mentioned law. However, this instrument of environmental management would only be regulated 20 years after its creation, with the publication of the Presidential Decree number 4,297, in July of 2002. Since then, a growing number of zoning works have sought to offer new methodological solutions for environmental planning and management in order to understand and mitigate anthropogenic influences on natural resources (Pires Neto, 1995; Silva & Santos, 2004; Fritzsons & Correa, 2009). Highlighted among these are the application of different techniques for zoning purposes based on the physical environment performed by Ohara et al. (1996), Rodrigues (2000), Lisboa (2001), Silva &Maniesi (2005), Santos et al. (2007) and Della Justina (2009) and development of several methods, such as Geotechnical Zoning (Vedovello, 1993), Agroecological Zoning proposed by Silva et al. (1993), Pedoclimatic Zoning developed by the Brazilian Agricultural Research Company (Embrapa, 1999), Socioeconomic and Ecological Zoning for Amazônia Legal, developed by the Secretariat for Strategic Affairs (Becker &Egler, 1996), Environmental Zoning from Remote Sensing, Proposed by Crepani et al. (1996, 2001) and Environmental Zoning, a method proposed by Jimenéz-Rueda (1991).

Despite the existence of previous works, which were directed to conservation units (CUs) in the Amazon, they generally privilege conservationist aspects and the interior of these areas. Occupancy in the buffer zones of CUs is a reality that continues to be relegated to the background in territorial management actions (Bastos et al., 2016). In the case in question, the characterisation and understanding of the environmental zones lead to a zoning proposal for the spatial planning in the Jamari National Forest and its surroundings as a means to assist in the prevention and mitigation of environmental impacts of positive feedback and indicate environments that are favourable to the needs of the population (Ohara, 1995). Therefore, the objective of this study was to identify environmental zones in the Jamari National Forest and its surroundings based on parameters of the physical environment as a demonstration of the viability of this method to subsidise macroplanning actions (1:100,000 scale) towards the spatial planning in conservation units of the Amazon and surroundings.

Location and physical environment of the study area: The study area comprises the Jamari National Forest and a 10 kilometre range in its surroundings, counting from the official demarcation line decreed by the federal government (Brasil, 2000), totalling 461,772 hectares (Figure 1). It is comprised between longitudes 62º44’05" and 63º16’54" W and latitudes 9º00’00" and 9º30’00" S. The unit has 223,086.27 hectares and was created by decree number 90,224, of 25/09/1984 (Brasil, 1984). The main access to the Jamari National Forest is from Porto Velho by land via the BR-364, travelling 110 km towards Cuiabá. The Jamari National Forest is part of the South-Amazonian cratonic structural unit of the South American Platform (Quadroset al., 2011), in a geotectonicstabilised region of the Neoproterozoic (Pires, 2009).

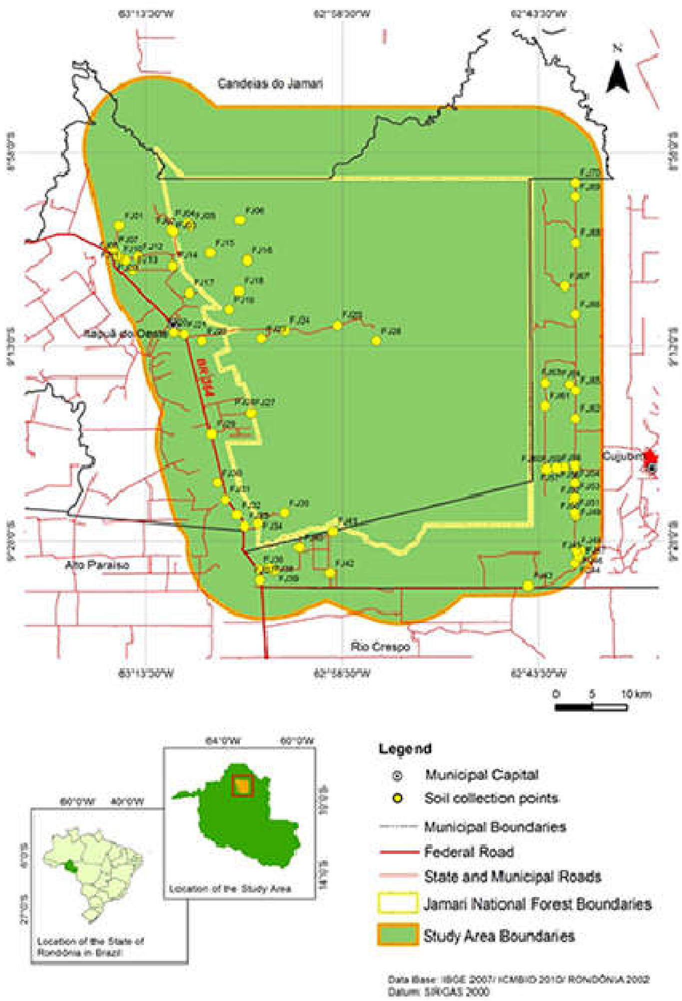

Figure 1. Location map of the study area and sampling point

The morphology shows, because of its age, flat surfaces originating from the reworking of pre-existing rocks, with a special configuration marked by morphoclimatic events, low dissection (Radambrasil, 1978; Adamy, 2002). Geological data from Scandolara et al. (1999) & Quadros (2010) show that the area is settled in its entirety on paleoproterozoic rocks of the Jamari Complex. It has mesoproterozoic rocks of Serra da Providência Intrusive Suite and neoproterozoicofYounger Granites of Rondonia, with more evidence in the southeast part of the area. It is also possible to notice the presence of coverings made by undifferentiated cenozoic sediments. Limits ranging from 100 to 300m were identified, characterised by the occurrence of extensive flattened areas, slightly carved by the drainage network (Radambrasil, 1978), which are often covered by lateritic detritus, generating low lateritic plateaus (Adamy, 2002), as verified in the western and northeast portions of the area. In the drainage network, the Jamari, Jacundá and Preto do Crespo rivers stand out, from the Jamari and Machado basins. The study area is located in a region characterised by relative spatial and seasonal homogeneity of temperature, with an annual average ranging from

24°C to 26°C (Gama, 2002). The area of the National Forest and its surroundings is among the highest rainfall averages of the state, between 2,400/2,600mm/year (Gama, 2002). By these characteristics, the climate is defined as Tropical Rainy, type Aw, hot and humid, according to the classification of Koppen. The periods of greatest rainfall are between November and May, with peaks in January and February. The decreases in rainfall levels occur at the end of May, with lower intensity recorded in June, July and August, reaching less than 20 mm/month. As for the soils, even at different scales, Radambrasil (1978) and Cprm(2007) 1:1,000,000 and Rondônia (2002) 1:250,000, they point to the almost total predominance of Latosols. Among these Latosols, the one of greater predominance in the area is the Dystrophic Yellow Latosol and secondly, the Dystrophic Red-Yellow Latosol (Radambrasil, 1978; Rondônia, 2002). These soils are considered of poor fertility due to deficiency of nutrients such as phosphorus, potassium and calcium (Fortuna, 1988). The exceptions were noted by Radambrasil (1978), which points out the existence of Hydromorphic Acrisols rich in alic quartz sands in the central-western part of the studied area and Rondônia (2002) which describes dystrophic Neosols spots in the centre of the conservation unit. Plinthsols were present in the northwest, southwest and east of the area. The most representative phytophysiognomy in the study area is the Submontane Open Ombrophilous Forest (Radambrasil, 1978; Silva &Vinha, 2002), which takes 95% of the unit (Brasil, 2005). There is a presence of Dense Ombrophilous Forest, northwest of the area, but significantly smaller in terms of coverage (Rondônia, 2002). This formation is adapted to soils with quaternary quartz characteristics (Rondônia, 2002).

MATERIALS AND METHODS

For the analysis of the entire area, a compartmentalisation was made in environmental zones by crossing their geological and geomorphological information that resulted in factors and properties that defined the homologous units (Jiménez-Rueda & Mattos, 1992; Shimbo&Jiménez-Rueda, 2007). The methods used were procedures of interpretation, processing and analysis of photographic images, remote sensing, radar, field visits for soil and rock collection, laboratory work to determine granulometric and mineralogical values, and petrographic analyses, and then return to the field to check and correct the information. These zones were represented in a map named environmental zones. These methods were used because they could indicate and ratify homologous characteristics of certain landscapes from properties of the physical environment named as environmental zones, with the purpose of implementing productive activities and of conservation of resources aiming at socioeconomic and environmental sustainability (Spörl& Ross, 2004; Montaño et al., 2007; Robaina et al., 2009).

Photo interpretation: Panchromatic aerial photographs were made available by Ibge(1979), 1:100,000 scale, photographic cover Project POLO 7/14, articulation 09º00' to 09º30'; 62º30'to 63º00', interpreted using the logical method of photointerpretation by deduction, induction and comparison proposed by Soares & Fiori (1976). A mirror stereoscope was used, brand Geoscope, model Stereo Aids. The zones were delimited by natural elements that were homologous on the landscape. Geological and geomorphological aspects were identified as prominent relief forms due to higher resistance of the material to erosion (positive ruptures), as well as the negative ruptures, which made possible to identify the organisation of the textural elements and to delimit different zones of texture properties and relief structure. The work of photo interpretation followed the analysis steps already used in works by Demattê&Demétrio (1995), Ohara et al. (2003) andAbarca (2005). 1) preparation; 2) preliminary interpretation; 3) preliminary recognition on the field; 4) reinterpretation and new field checks; and 5) finishing and editing the map of environmental zones. The interpretation of the photographs was later vectorised on a tablet in the geotechnology laboratory of CPRM/Porto Velho, where a file of the shapefile format was generated, which is manageable in different programs.

Remote sensing: The images of the remote sensors were used to adjust the environmental zones by their synoptic view of the area (Florenzano, 2002), due to the size of the Jamari National Forest and to present morphosculpture information (Ross, 2009). Besides the visual analysis, the comparison between pixels, texture and colours was made (Perrotta, 2005), which allowed to obtain information about the Geology as boundary identification of the areas with granitic rocks. It was also possible to obtain information about the Geomorphology, such as roughness of the drainage network and of the vegetation, forested and non-forested areas (Camargo et al., 2004). For the 2013 studies, images of the Landsat 8 satellite were used, orbit and line 232-66, Operacional Terra Imager sensor (OLI), with a spectral range of 0.45 to 0.88 mm, spatial resolution of 30 meters and temporal resolution of 16 days. After scanning, the digital file could be superimposed on the 2013 satellite image of the delimited areas. This procedure consisted of the visual analysis of the terrain, considering elements such as shape, size, colour and pixel patterns to identify possible differences between the image and the zones identified for adjustments and reedition of the zones' shape and of textural elements of the image, such as rocky outcrops and flooded areas.

Radar Images: With the purpose of refining the map and the boundaries of the environmental zones, data from the Digital Elevation Model(DEM), of the project "Shuttle Radar TopographyMission"/Nasa (Rabuset al., 2003; Miceli et al., 2011), C-bandand data from the project Topodata(Brasil, 2008; Valeriano andAlbuquerque, 2010), images 8S645, 8S63_, 9S645 e 9S63_ were used. This work consisted of superimposing the shape file generated on the tablet for visual comparison of the areas delimited with the geomorphological information of the radar data (Figure 2). The areas for adjustments were identified and the shape of the zones was reedited with the corrections.

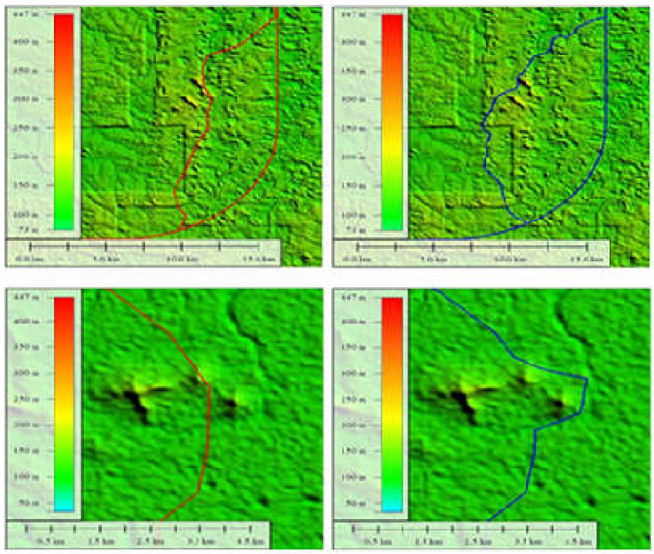

Figure 2. Examples of adjustments made to establish environmental zones through the use of the images from the Shuttle RadarTopographyMission/SRTM (2000)

Fieldwork: The objective of the field activities was to verify *in loco* landscape aspects related to the delimited environmental zones as for geological and geomorphological characteristics, as well as to collect soils and rocks for granulometric, petrographic and mineralogical analyses. At the end of the laboratory work, a return to the field was made to validate the collected information and integrate them for adjustments of the environmental zones map. Information collection was performed at 70 points in total, according to Figure 1. The in-line transection method was used (Santos et al., 1995), in which observations and/or collection was done whenever changes were noticed in the environment, or when some important environmental characteristic was noted. Of the total points that were visited (70 points), soil and rock samples were collected in 20 of them for granulometric, mineralogical and petrographic analyses, as well as for photos and demarking of control points. These points were organised alphanumerically under the title "FJ" and numbered from 1 to 70.

Laboratory Work

Granulometry: The granulometric analyses identified the different proportions between sand, silt and clay of the collected materials in 18 selected samples. For the purpose of separating these fractions, a shaker was used for the fractions of sand grains (Souza et al., 2003; Sanchez et al., 2009; Dourado et al., 2012), and laser diffraction for silt and clay (Beuselinck et al., 1998; Schneider &Souza, 2004). To select the sand fraction, the samples were worked through wet sieving using standard series of sieves superimposed from the highest to the lowest mesh with opening diameters of 5, 10, 20, 40, 60, 100 and 150. The result represents the relative frequency with which the different sizes between an upper bound and a lower bound are present in the population of particles. After sieving, these were dried in an air circulation oven to define weights and representation of each sample, according to Gomes (2009), Santos (2010) and Nascimento et al. (2012).For silt and clay fractions, a Cilas 1064 laser granulometer was used. The Wentworth method (1922) was used for sieving in order to classify the different granulometric fractions.

Petrography: Initially, this work phase was directed for description and the mesoscopic petrographic analyses, with the purpose of selecting samples for the subsequent microscopic examination (samples FJ-10 and FJ-66) in order to know the nature of the rocky basement of the environmental zones from making thin sections. The initial preparation to make thin sections was done at the Geological Survey of Brazil (Cprm/Porto Velho), cutting the rock into 2 x 4 cm slices. For the next step, the rock slices were sent to the Geological Survey of Brazil (Cprm/Manaus) to polish the sample with abrasive powder in the polisher until it was down to the thickness of 0.03 mm, which was verified by the interference colour quartz grains. The thin sections were examined in the Geological Survey of Brazil (Cprm/Porto Velho), using a Carl Zeiss binocular petrographic microscope under polarised light. These studies allow the microscopic characterisation of minerals, texture and structural features of rocks and laterites by taking photomicrographs (Nascimento et al., 2012), besides identifying the detrital and autigenic constituents in sedimentary rocks, as well as assessing the modal percentages of its minerals.

Mineralogy: These analyses were carried out in the laboratory of the Federal University of Paraná, responsible for the qualitative analysis of minerals and clay minerals through the total pressed powder using X-ray diffraction (Campos et al., 2013) and in the Geosciences Laboratory of the Federal University of Rondônia, responsible for the mineral quantification of the sample in the granulometric range of the sand fraction (Wentworth, 1922) with the use of a binocular loupe in 18 previously selected samples. For each granulometric class, from very coarse sand to very fine sand, the characteristics of the grains and the degree of rounding were taken into account, as well as for mineral determination from its properties such as: colour, brightness, cleavage, magnetism, aspect, hardness and transparency.

RESULTS AND DISCUSSIONS

The following environmental zones are the result of the subdivision of the study area into homologous environments, which could reduce to the maximum, within the proposed scale, their variability according to the classification parameters and characteristics used to distinguish the zones. This classification resulted in the delimitation of five zones (Figure 3): Jacundá (246,634.19 ha, 53.41%), Itapuã (71,971.09 ha, 15.58%), Nascente (68,211.93 ha, 14.77%), Laterita (65,295.46 ha, 14.14% ha) andCujubim (9,659.24 ha, 2.09%). The establishment of zones allowed them to be represented cartographically and the spatial distribution of their aptitudes to be visualised in a single map, favouring the interpretation of regional planning activities, allowing greater integration between data and information.

Jacundá Environmental Zone: It is the most representative Environmental Zone, occupying 246,634.19 hectares, corresponding to 53.41% of the study area. It is characterised by slightly corrugated interfluves in a medium dissected relief, including possible hillocks and tors, and medium slope rupture density. As rocky substrate, it has the paleoproterozoic gneisses of the Jamari Complex and mesoproterozoic granites of theSerra da Providência Intrusive Suite. Field data, and granulometric and mineralogical analyses showed the presence of immature eluvial soils in the Jacundá Environmental Zone for having thicknesses lower than 1 meter, absence of B horizon or in formation and lithic fragments in significant amounts (38%). They are red litholic soils, having sand and silt + clay fractions, with higher grain richness in the sand fraction, with predominance of quartz (53%) in poorly selected grains (Table 1). The lithic fragments are from the Jamari complex gneisses with smaller dimensions than pebbles and are found in gradual quantities, from the largest to the smallest proportion, in the granulometric fractions of sand from the thickest to the thinnest (Table 1; Figures 4A and 3B). Thus, the very coarse sand fraction exhibits 51% content of lithic fragments and in the coarse, medium and fine sand fractions, the contents are between 5% and 30% (Table 1). The quartz grains in the sand fraction occur in three ways, in increasing order of quantity: white transparent clear monocrystalline crystals, milky white polycrystalline grains and brown clear polycrystalline grains. They are grains that have stains on fractures and pores of reddish colours of iron oxides and hydroxides from a secondary origin. The petrographic analysis in thin sections of the original rock revealed a mineralogical composition based on quartz (35%), orthopyroxene (25%), garnet (20%), hornblende (15%) and opaques (5%), besides traces of actinolite and biotite, with garnet and quartz porphyroblasts of up to 4 mm immersed in aequigranular granoblastic matrix with average sizes of 0.3 mm (Figure 4C).

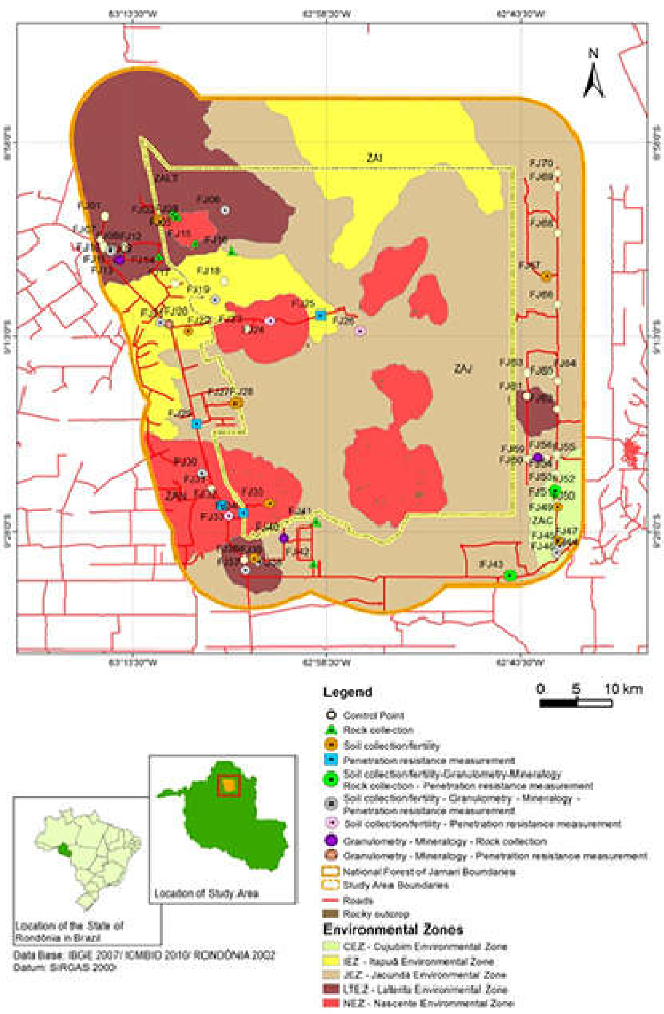

Figure 3. Map of environmental zones with collection and control points

Table 1. Distribution of sand and silt + clay fractions and estimates in percentage by volume of the minerals of the sand fraction in the soil of the Jacundá Environmental Zone. % Sand + % silt + % clay = 100%. % coarse sand + % medium sand + % fine sand + % very fine sand = % sand fraction (Point FJ-40)

GRANULO-METRIC FRACTION	% WEIGHT	MINERALS (% in volume)						
		Quartz	Feldspar	Mica	Opaques	Zircon	Lithic Fragments	Iron Oxide/Hy-droxide
SAND	51	53	2	< 1	2	< 1	38	5
coarse sand	30	65	1	-	1	-	30	3
medium sand	5	82	1	-	6	-	7	4
fine sand	16	84	1	< 1	6	< 1	6	4
SILT+CLAY	49							

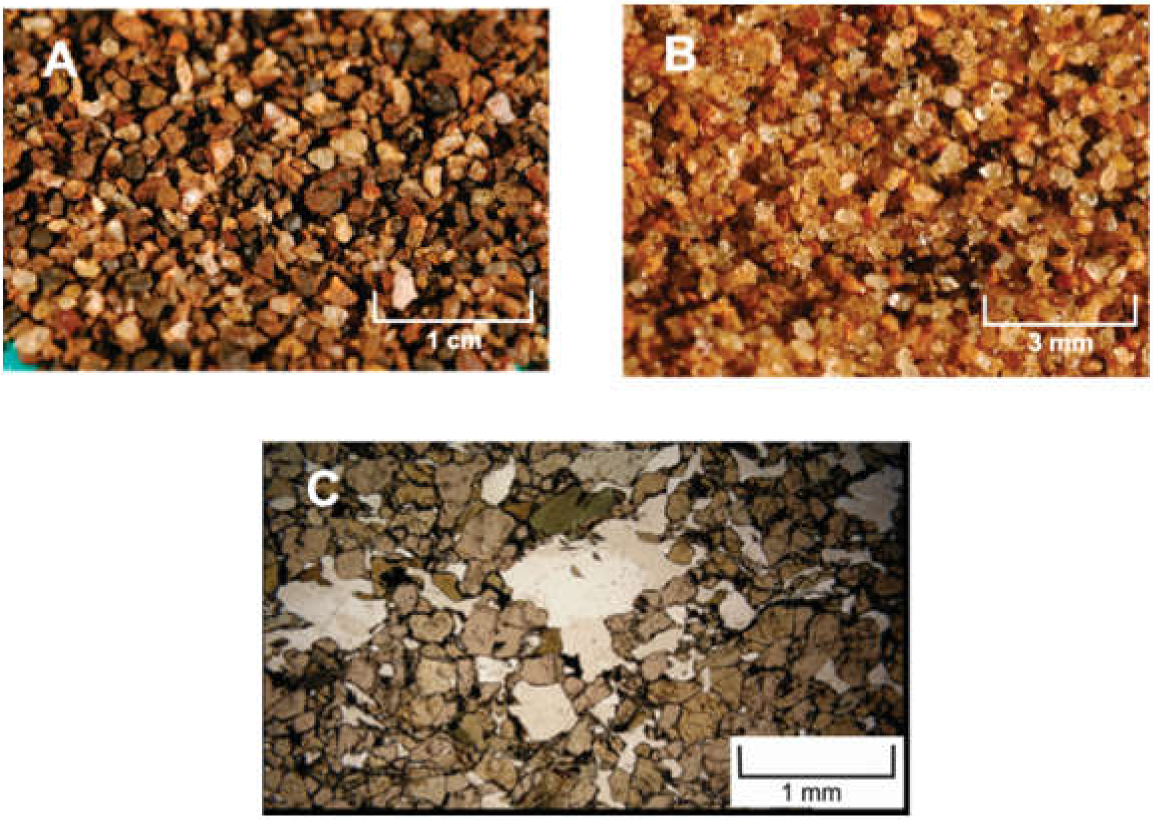

Figure 4. Photos of the granulometry and photomicrographs of the Jacundá Environmental Zone. (A) Grains in the coarse sand fraction made of lithic fragments (51%) of gneisses from the Jamari Complex and quartz (46%). (B) Grains in the very fine sand fraction made of lithic fragments (5%) of gneisses of the Jamari Complex and quartz (86%). (C) Photomicrograph showing gneiss of the Jamari Complex with microporphyroblasts of quartz immersed in a quartz, garnet, hornblende and opaque based equigranular granoblastic matrix (Point FJ-40). Author: Vanderlei Maniesi

In addition to eluvial soils, there are also colluvial soils on the granitoids of Serra da Providência Granite Suite. They are of little evolved pedogenesis, evidenced by the development of the soil structure with absence or incipience of B horizon and absence of C horizon (deformed granitic saprolite). In the sand fraction, the quartz behaves in a very stable way in relation to the weathering dissolution of other mineral phases (Figure 4B). Thus, during the course of weathering and erosion, the sediments are gradually enriched in quartz (46 to 86%) and depleted in feldspars (2 to 0%), and in other easily weathered primary minerals, such as pyroxene, amphibole and garnet. In this weathering process, the easily weatherable minerals are leached, leaving those with less mobility, clay minerals and solutions of iron oxide and hydroxides, characterised with red hues. They are soils that have rounded pebbles of quartz and laterite with an average diameter of 1 to 6 cm, in a soil with intermediate texture between sandy and silty-clayey. The active process of stony ground formation relates to the dependence of morphogenesis of a progressive action of physical weathering on an exposed sub-rocky ground (Ab'Saber, 1969).

Itapuã Environmental Zone: The Itapuã Environmental Zone is the second most extensive, representing 15.58% of the study area (71,971.09 hectares). It covers the urban centre, surroundings of Itapuã do Oeste and the northern centre portion of the Jamari Tropical Forest and surroundings, bathed by the Janipapo river, an affluent of the left bank of the Jacundá river. It is defined by two respectively continuous areas with low density of the relief features and drainage, in a first order structure, having characteristics of high water retention capacity and good permeability in a relief with low dissection. It is an environmental zone with a wide distribution in the western portion of the Jamari National Forest and surroundings, with cenozoic sedimentary materials derived from alluvial fans, fluvial channels, flood plains and lacustrine of plio-pleistocene age, with thickness generally inferior to 40 meters, according to interpretation of Quadros & Rizzotto (2007).These soils lack essential nutrients, and the constant high luminosity, temperature and humidity are reflected in the natural vegetation. The granulometric and mineralogical data of the soils and sediments show that most of the nutrients are contained in the vegetation in decomposition process. They are nutrients with sufficient quantity only for the cycle, establishing in a fast decomposition of the vegetal remains, releasing mineral nutrients, which are reabsorbed by the roots. There are contraction cracks in the compacted material due to intense trampling of cattle, but without significant linear erosive processes. The sedimentary material is made of millimetric to sub-millimetric quartz grains, faceted and sub-rounded, enveloped by aclayey silty matrix of medium graycolour with ocher clayey portions. In the sand fraction, grains with a degree of predominantly angular and subangular roundness are identified, consisting of quartz (94%), lateritic fragments (5%), opaque (1%) and feldspar (traces), Table 2. The transparent quartz grains overlap the milky ones in quantity. Its low degree of roundness and flattened grains (oblate) suggests its original form of autogenous material, now disaggregated. They eventually have reddish spots and associated lateritic aggregates in the grains of the very coarse and coarse sand fractions that are resistant to transport (Figure 5B). The opaques are represented in greater proportion by the ilmenite and in a subordinate way by the magnetite. They are present as isolated grains in fractions smaller than 0.5 mm, or as fine primary inclusions in quartz grains, or even as spots on the lateritic fragments, along with fine rounded quartz grains. The muscovite appears in fractions finer than 0.25 mm in angular to subangular clear laminar particles. These sediments have a predominance of sand fraction (89.9%) in relation to silt + clay (10.1%). The binocular loupe identified the mineralogy in the sand fraction as quartz (94%), lateritic fragments (5%), opaque (1%) and feldspar (traces).

expressive gradient, they form divisors of hydrographic sub-basins with drainage areas having undeveloped alluvial plains and places of relative abundance of springs. In the central and southwestern portions of the Jamari National Forest, the drainage network of the Nascente Environmental Zone appears as anomalous forms (radial pattern), with divergentdrainage elements and well defined asymmetry. They have alluviums of reddish colour, that may eventually exceed 1 meter in thickness, with a salient presence of pebbles and angular boulders dispersed in milky quartz and centimetric mica pieces, indicating a well differentiated granite material as original rock, Rondônia Intrusive Suite, of neoproterozoic age. The soil collected in the sample (Table 3) shows the predominance of particles in the silt + clay fraction (69.5%) in relation to the sand (30.5%), with the following mineralogy of the sand fraction: quartz (60%), Lateritic fragments (22%), opaque (18%), feldspar (traces), mica (traces) and zircon (traces). Primary deposits of cassiterite are exploited by mining companies in the Nascente Environmental Zone. They are minerals located in the top portions of domes of granitic intrusions and country rocks by hydrothermal processes, being associated or not with zinnwaldite, topaz, wolframite and columbite-tantalite (Leite Júnior, 2002). Secondary deposits are also found in the Nascente Environmental Zone, originary from the weathering of mineralised zones of granitic and country rocks through chemical decomposition, mechanical disintegration, erosion, transport and deposition processes.

Table 2.Macroscopic estimate of percentage by volume of the minerals of the sand fraction in the soil of the Itapuã Environmental Zone. % Sand + % silt + clay = 100%; % Coarse sand + % medium sand + % fine sand + % very fine sand = % sand (Point FJ-17)

GRANULOMETRIC FRACTION	% WEIGHT	MINERALS (% in volume)					
		Quartz	Feldspar	Mica	Opaques	Tourmaline	Lateritic Fragments
SAND	89.9	94	< 1	-	1	< 1	5
coarse sand	39.9	96	-	-	-	-	2
medium sand	31.8	95	-	-	2	-	3
fine sand	18.2	84	-	< 1	4	-	12
SILT+CLAY	10.1						

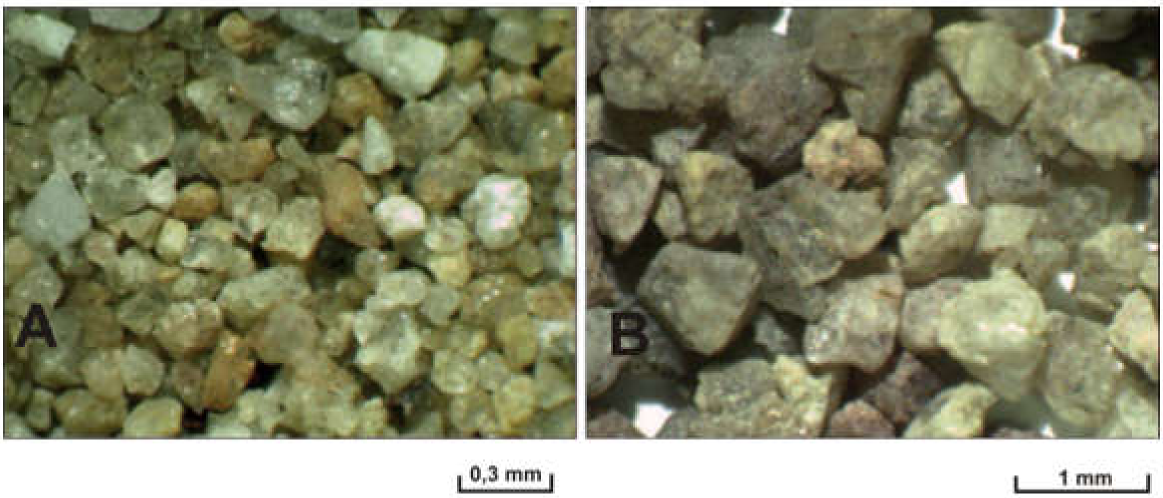

Figure 5. Monomineralic quartz crystals predominant in fine sand (A) and coarse sand (B) fractions. Point FJ-17. Author: Vanderlei Maniesi

The soil is made of a quantity of mineral nutrients bioavailable as a consequence of the pedoenvironmentalconditions under which they are formed, and are in continuous modification in adaptation to the new dominant environmental conditions.

Nascente Environmental Zone: The Nascente Environmental Zone is represented by 6 discontinuous portions with varying dimensions, the smallest having a diameter close to 3 km and the largest one with diameters close to 24 km. Altogether, it occupies an area of 68,211.93 hectares, which corresponds to 14.77% of the study area. It represents a dense cluster of hills with medium to high dissection, whose tops are rounded due to the spheroidal disjunctions and their slopes with convex, sometimes rectilinear profiles. Due to their relatively

During the weathering process, cassiterite behaves as a resistant mineral found in colluvial, alluvial deposits and also in paleovalleys associated with paleoclimatic conditions, as highlighted by Porsaniet al. (2004).

Laterita Environmental Zone (LTc and LTi): The Laterita Environmental Zone shows indications of intensely drained paleosurfaces and plays a significant role in the relief configuration, having hilly formations (LTc) and lowered surfaces (LTi), sculpted according to the resistance to the weathering processes of the outcropping portion (forms and processes). They are distributed in 14.14% of the study area, which means a total of 65,295.46 hectares.

The Laterita Environmental Zone is made of laterites with incomplete profile development, discontinuously covering mesoproterozoic granitic rocks, located in the northwest, southwest and east-central portions of the Jamari National Forest and surroundings. With the current weathering, the lateritic materials LTc and LTi are associated with reddish eluvial soils and occasional colluvium, both not very thick (less than 1 meter), with ferruginous concretions (structure).

Table 3. Macroscopic estimate of percentage by volume of the minerals of the sand fraction in the soil of the Nascente Environmental Zone. % Sand + % silt + clay = 100%; % Coarse sand + % medium sand + % fine sand + % very fine sand = % sand (Point FJ-31)

GRANULOMETRIC FRACTION	% WEIGHT	MINERALS (% in volume)					
		Quartz	Feldspar	Mica	Opaques	Zircon	Lateritic Fragments
SAND	30.5	60	< 1	< 1	18	< 1	22
coarse sand	3,0	43	-	-	21	-	36
medium sand	15,4	77	-	-	8	-	15
fine sand	12,1	69	< 1	< 1	21	-	9
SILT+CLAY	69.5						

Table 4. Granulometric distribution in percentage by weight of the pebble, granule, sand, silt and clay fractions and estimates in percentage of minerals by volume of the pebble, granule and sand fractions in the soil of the Laterita Environmental Zone (Point FJ-36)

GRANULOMETRIC FRACTION	% WEIGHT	MINERALS (% in volume)			
		Quartz	Opaques	Lateritic Fragments	Nodules of Kaolinite
PEBBLE	71.1	-	-	98	2
GRANULE	4.9	-	-	99	1
SAND	10	35	18	38	9
coarse sand	5.3	15	-	75	10
medium sand	1.2	26	2	67	6
fine sand	2.5	31	20	44	5
SILT+CLAY			14.0		

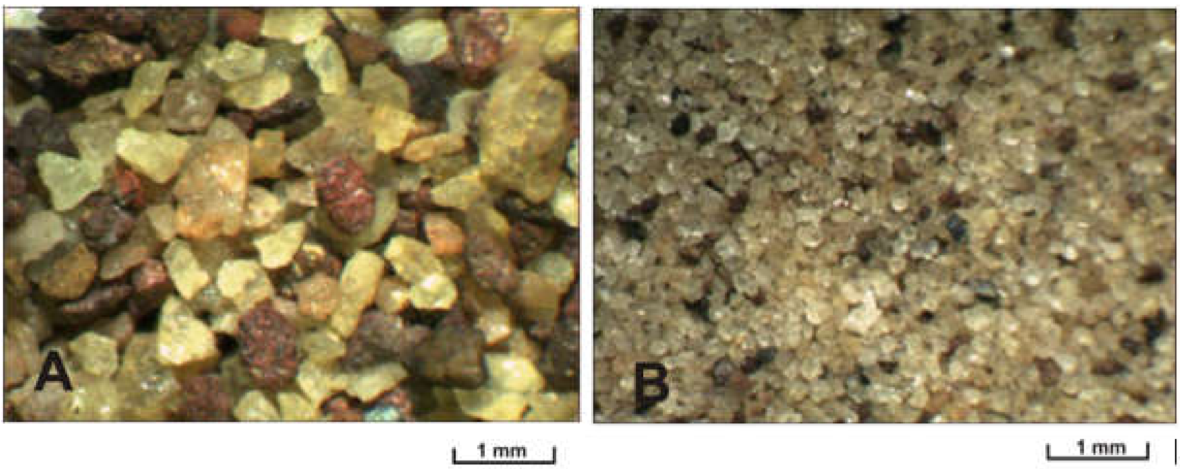

Figure 6. Enrichment of opaque minerals and depletion of lateritic fragments in the finer fractions of incohesive lateritic material (LTi). A = coarse sand fraction; B = fine sand fraction (Point FJ-36). Author: Vanderlei Maniesi

Cohesive Laterites (LTc): They are originated from structured arrangement of convex ruptures in the landscape, constituting relief ridges in spreading hills as a result of the great resistance of the material to erosion. They are more prominent relief forms, in relation to the rest of the Laterita Environmental Zone. These geomorphological features favour deposition in the surrounding terrain (aggradation), due to the presence of accentuated topographic gradient and to the current intense erosion processes. The cohesive lateritic materials (LTc) are arranged sub-horizontally, hardened in metric prismatic columns with the presence of nodules and pisolites dispersed in metric prismatic columnar structures. They have nodules and pisolites with irregular to sub-spherical forms, with millimetric to centimetric diameters and are strongly cemented by clayey material, forming compact aggregates. The microscopic mineralogical analyses showed that they are laterites made of a microcrystalline ferruginous matrix of reddish browncolour. They have a breccioid aspect with dispersed pores and millimetric subspherical pisolites with concentric blades (or bands), evidencing successive precipitations, and colour alternating between the reddish brown and yellowish brown tonalities. The crystals of quartz, therefore, are arranged next to the pisolites, veins or even dispersed in the microcrystalline ferruginous matrix. They are residual, anhedral, with diameters lower than 0.1 mm and with corroded edges, suggesting dissolution, as well as past deformation of the mother rock with microfractures and moderate to strong undulating extinction. They cause impediments to agricultural mechanisation due to the formation of hardpans or ferruginous shells (cohesive laterite -LTc) and restriction to the plants rooting, even with the suspended water table due to the infiltration blockage caused by the cohesive ferruginous shells.

Incohesive Laterites (LTi): The development of lowered surfaces in the Laterita Environmental Zone is associated with lateritic profiles with exposure to ferruginous incohesive materials (LTi). The resulting relief pattern delineates a slightly undulating morphology in positions that imply slow drainage and temporary flooding, as well as wide valleys with low slopes. The values for the granulometric percentages of the sand, silt and clay fractions (diameters <2 mm), as well as the mineral distribution in the pebble (64 to 4 mm) and

Table 5. Granulometric distribution in percentage by weight of the pebble, granule, sand, silt and clay fractions and estimates in percentage of minerals by volume of the pebble, granule and sand fractions in the soil of the Laterita Environmental Zone (Point FJ-61)

GRANULOMETRIC FRACTION	% WEIGHT	MINERALS (% in volume)		
		Quartz	Lateritic Fragments	Nodules of Kaolinite
PEBBLE	64	-	81	19
GRANULE	5.9	-	83	17
SAND	15	18	47	35
coarse sand	8.3	7	61	32
medium sand	1.9	11	69	20
fine sand	4.8	12	51	37
SILT+CLAY	15.1			

Table 6. Granulometric estimation for the intervals of 0-20 cm (A) and 20-40 cm (B) of soil depth collected in points FJ-44 and FJ-47 under forest, and FJ-45 and FJ-52 under pasture. % Granule + % pebble + % sand + % silt + clay = 100%; % Coarse sand + % medium sand + % fine sand = % sand

GRANULOMETRIC FRACTION	FJ-44A	FJ-44B	FJ-45A	FJ-45B	FJ-47A	FJ-47B	FJ-52A	FJ-52B
PEBBLE + GRANULE	0.1	0.01	1.11	2.58	0.42	0.71	0.16	0.44
SAND	33.25	20.79	64.04	42.63	31.67	30.77	76.78	63.05
coarse sand	18.62	13.02	34.99	27.77	21.86	21.25	46.12	34.8
medium sand	14.54	7.75	12.2	2.56	9.8	9.5	15.95	13.53
fine sand	0.1	0.02	16.85	12.3	0.01	0.02	14.71	14.72
SILT+CLAY	66.65	79.20	34.85	54.79	67.91	68.25	22.06	36.51

granule (4 to 2 mm) fractions of the selected samples are listed in Tables 4 and 5. They represent aggregates resulting from the dismantling of the cohesive laterite (LTc) with predominance of the pebble, sand and granule fractions, surrounded by a reddish clayey material, because of the current ease of water circulation, accelerating the weathering process of the lateritic fragment. The composition of the pebble, granule and sand fractions shows the mineral distribution pattern with a clear trend of laterite grain depletion and quartz enrichment (Tables 4 and 5, Figure 6) in their rounded grains. The mineralogy is based in residual minerals with quartz and traces of feldspar, mica and opaques. They constitute soils of low natural fertility due to their genetic nature of intense leaching, with limitations to its use also due to the agglomeration of lateritic concretions (petroplinthite) with predominant presence of gravel fractions, hindering the use of agricultural equipment. They are incomplete ferruginous lateritic profiles with immature nature, that is, of low evolution, and it is possible to recognise all over the profiles the ferruginous horizon with the cohesive and incohesive zones, and eventual similarly mottled horizons that happen in the lateritic profiles of the urban area of Porto Velho (RO) defined by Nascimento et al. (2012).

Cujubim Environmental Zone: The Cujubim Environmental Zone is restricted in the southeastern end of the Jamari National Forest area and surroundings, which makes it the smallest unit among the others, with a total area of 9,659 hectares, which is about 2.09% of the studied area. It is a portion of the levelled terrain that has as its peculiarity the conjugation of residual granitic reliefs with slightly undulating plains covered by a layer of eluvial weathering. In the central and southeastern portions of this zone, there is a low density of slope ruptures as textural elements of the relief and low drainage density, which may characterise a greater fluid percolation potential when compared to other zones in the eastern part of the unit. This conformation provides the generation of a relief of smooth plains and open valleys related to the advance of the weathering alteration along the sub-horizontal planes, which causes exfoliations in the granitic rock (Santa Clara Intrusive Suite), forming curvilinear plates of some millimetres of thickness, and their peeling tends to form rounded surfaces and, thus, creating soft hills in a little dissected relief. This granitic formation, present in the northwestern part of the zone, is represented by hills as residual reliefs (inselbergs) that during the geological time were dismantled and adjusted to the base level of the planed surface, generating a more dissected relief. It is a process of dismantling and levelling of the residual reliefs represented by hillocks, which are hills less exuberant than the inselbergs, not exceeding 50-70 meters of gradient, but with sharp slopes, sometimes covered by rock fragments in their tops and/or slopes. The tors, with gradient differences of less than 30 meters, have rocky outcrops, intensely fractured and fragmented in blocks and boulders. The fields of boulders as representative of the final levelling of the inselbergs happen with the complete destruction of the tors, configuring a landscape with sets of boulders with diameters of up to 6-7 meters. When solid granitic rock formations are on the surface, then variations in the relief configuration occur within the same environmental zone. They are variations of more ordered texture elements observed in aerial photographs, which are marked by the ruptures of convex slopes towards the alignment of the relief forms that are more resistant to weathering processes and to removal. Moreover, in depths greater than 20 cm from the ground, there is a strong migration of silt-clayey material from the upper part of the profile to the lower one. While in the soils under forests this migration ranged from 1 to 19%, in soils under pasture this variation reached 58%, according to Table 6.

CONCLUSIONS

The study in this scale (1:100,000) allowedthe identification of five environmental zones in the Jamari National Forest and surroundings from the physical environment parameters, and they were called Jacundá Environmental Zone (246,634.19 ha), Itapuã Environmental Zone (71,971.09 ha), Nascente Environmental Zone (68,211.93 ha), Laterita Environmental Zone (65.295.46 ha) and Cujubim Environmental Zone (9,659 ha). The delimitation of the environmental zones supported by mineralogical and granulometric data shows that the soils are pedogenetically poorly developed, sandy and have a high quartz richness (84.9% Nascente Environmental Zone, 91.25% Jacundá Environmental Zone, 88.47% Cujubim Environmental Zone, 72.98% Laterita Environmental Zone and 88.68% Itapuã Environmental Zone - mean value in the sand fraction) and lithic fragments, andare unlike to crop agriculture. The granitic environments, Nascent Environmental Zone and Cujubim Environmental Zone, presented better productive capacity in relation to the other zones, Jacundá Environmental Zone, Laterita Environmental Zone and Itapuã Environmental Zone. The use of the zoning method to understand the characteristics of the physical environment based on the interdisciplinary analysis of environmental attributes makes it possible to orient spatial planning and management policies based on technical criteria that sustain society and nature relations to maintain and improve the conditions of the use of natural resources in rural properties located around conservation units.

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