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EROSIVE PROCESSES IN URBAN AREAS IN THE ISLAND OF MARANHÃO – BRAZIL

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ABSTRACT

Urban erosion in Brazil can be related to the lack of a planning that considers the particularities of the environment and the socioeconomic conditions of the urban development. In that sense, the occurrence of erosive processes generally is associated to areas of irregular population settlement, where there is no planning. Along the Island of Maranhão it may be encountered rills and gullies on those areas, putting at risk houses and people's lives. The main factors of superficial and subsurface water flow, that generate rill and gully processes, are the soil properties, rain regime, characteristics of the slopes, soil use and deforestation. In that sense, the environmental situation observed in São Luís is prone to gullying. Rocks of high porosity and low hardness are found. It is one of the most dissected parts of the Island of Maranhão. The annual rain regime is marked by a rainy period and another one with rain deficiency. The soils present, in tactile-appearance identification, high contents of sand and silt and clear colours, which are the evidence of low organic matter content. The original vegetation cover has been cleared intensely. Considering the current conditions, the soils are, in general, very susceptible to the erosive processes, mainly when submitted to human intervention, without planning. Monitoring of the erosive processes carried out since January 2001 demonstrates a recurrence of soil erosion, where the vegetation was removed, on slopes between 5^{o} and 15^{o}, occupied by irregular population settlements, without basic urban infrastructure, especially sanitation, rain pipes and paved roads. The erosion presents itself more intense in those areas of recent demographic expansion, where

areas with potential environmental risk can be found, provoking land degradation and silting up of the water bodies, patrimony losses and death risk. Therefore, the understanding of the factors that generate erosive processes, as well as the application of control measures and prevention are fundamental actions to the public safety.

Keywords: gully erosion, irregular settlement, soil properties, deforestation

INTRODUCTION

Along several years, numerous studies (Ab'Saber, 1968; Christofoletti, 1968; Vieira, 1978; Deringer, 1984; Sobreira, 1989; Almeida *et al.*, 1991; Bucci *et al.*, 1991; Silva & Politano, 1995; Xavier, 1996) have been demonstrating that the urban erosion in Brazil is associated to the lack of planning that considers the particularities of the environment and the socioeconomic conditions of the urban development. In that sense, the occurrence of erosive processes is generally associated to areas of irregular population settlement, where almost always there is no planning. In São Luís's city, State of Maranhão's capital, along the Island of Maranhão (Figure 1) this situation is represented where gullies are frequently developed by diverse causes.

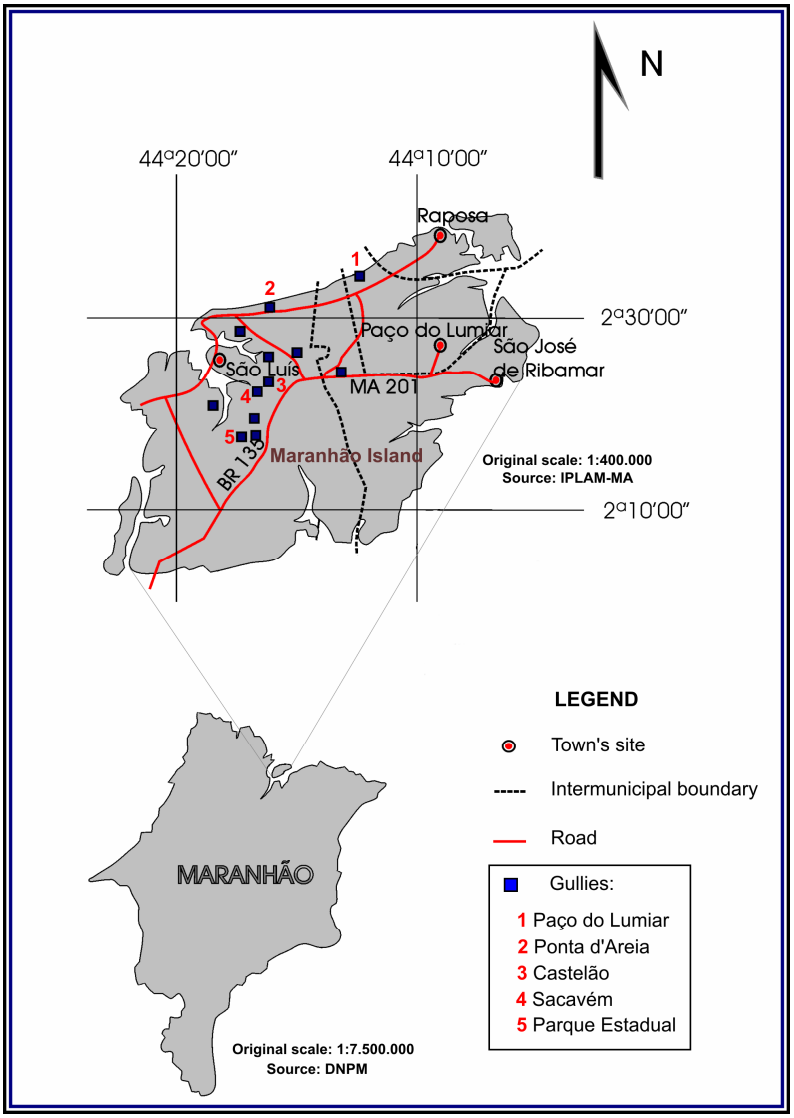

Figure 1: Location of the study area and gullies.
(Source: Mendonça, 2003; modified).

According to Mendonça (2003), the erosive processes in Maranhão are very severe, and deforestation is one of the main causes in areas of accelerated urban expansion. In the municipal district of São Luís and surroundings, several places are found with erosive features in large scale. In some cases, the houses and people's lives are at risk (Figures 2 and 3).

The main causing factors of runoff and subsurface flow, that provoke gullying, are soil properties, annual rain regime, slope parameters, soil's use and deforestation (Middleton, 1930; Horton, 1933; Bouyoucos, 1935; Bennet, 1939; Zingg, 1940; Horton, 1945; Ellison, 1947; Sreenivas *et al.*, 1947; Morgan, 1986; Guerra, 1996).

Figure 2: Aerial view of the Sacavém gully: Note proximity to the houses (at left), which unevenness with the gully's basis is four meters approximately.
(Source: Embrapa, 1999, scale: 1:4.000; extracted of: Bezerra, 2003, modified)

Figure 3: Paço do Lumiar city's gully: Note the presence of houses at the top of the photo, threatened by the progress of the gully (Photo: Sathler, 2004)

In that sense, the environmental situation observed in São Luís is prone to gullying. The geology of the area is predominantly Tertiary, presenting sandstones, schists, claystones and siltstones proceeding to the Itapecuru and Barreiras Formations (Lisboa, 1914; Campbell, 1949; Klein, 1975; Martins 1996). Those rocks are of high porosity and low hardness, very susceptible to weathering and erosion (Guerra *et al.*, 2004). It is one of the most dissected parts of the Island of Maranhão, presenting tabular and subtabulars tops that limit with alluvial plain under the form of steep barriers exposed to the action of the geomorphic agents. The annual rain regime is rather irregular, being marked by two different periods: the rainy one with moderate to high rain surpluses and another one with rain deficiency (Mendonça, 2003). The soils present, in tactile-appearance identification, high contents of sand and silt, and clear colours are the evidence of low organic matter contents. The original vegetation cover has been cleared intensely by the urban expansion, being substituted by secondary or regenerative vegetation (Guerra *et al.*, 2004).

The characterization of the pedologic and geologic materials, as well as the environmental conditions, found in the places under the action of intense erosive processes, can give support to the identification of the generating and/or controlling mechanisms of the erosive processes of the Island of Maranhão. Such identification is essential to the handling and recovery of the degraded areas.

The researches developed together between Federal University of Rio de Janeiro (UFRJ) and Federal University of Maranhão (UFMA) are parts of a project sponsored by the European Union, entitled "The Environmental and Socio-economic Contribution of Palm Geotextiles to Sustainable Development and Soil Conservation", or simply Borassus. Borassus's general proposal is to promote the development of common integrated approaches necessary to implement sustainable development in global level. It aims to foster the international cooperation starting from the convergence of European and other national research efforts, to achieve common strategies to respond to global change issues. The aim of this novel proposal is to develop, to investigate and to validate geotextil mats made from Borassus aethiopum and structurally-similar palm species. Preliminary investigations suggest that this could be an effective and cheap soil conservation method with enormous global potential (European Commission, 2004). Locally denominated "Gully monitoring, management and rehabilitation of eroded slopes in Brazil, through sustainable employment and social awareness", or merely Borassus-Reade (Recovery of Degraded Areas).

OBJECTIVES

The general objective of this study is to investigate the evolution of the erosive processes in the Island of Maranhão, Brazil, starting from the identification, location and characterization of the occurrence areas, as well as of the erosive features monitoring. It has been focusing the gullying evolution above all, due to the recurrence of those erosive features along the island, as well as due to the fact they affect large areas and constitute enormous environmental risk, of landslides and of death.

An environmental analysis of the landscape evolution and its dynamics make it possible to verify its vulnerability to the soil's uses, as well as to evaluate and to map the processes and forms as society and nature interact.

MATERIALS AND METHODS

Aiming at the soils and sediments characterization found at the points under influence of accelerated erosive processes, samples have been collected for analysis in the Laboratory of Environmental Geomorphology and Soil Degradation of the Department of Geography and in the Sector of Engineering Geology and Environmental of the Department of Geology, both in the Federal University of Rio de Janeiro.

Primarily, four gullies have been selected (Figure 1), in which soil samples have been collected. All the gullies are in grass-covered areas. Castelão's gully is in initial state of formation and represents landslide's threat to the parking area of the Castelão Football Stadium, of the São Luis's City. Ponta d'Areia's gully is bigger in length and depth, and is eroding the cliff face of the beach of the same name; its progression can generate landslide risk to the Lighthouse of Ponta d'Areia and the hotels nearby. Parque Estadual's and Sacavém's gullies are bigger in length and depth amongst the selected ones, being Sacavém the most extensive and deeper of all. This one puts at risk of death and landslide people and houses nearby.

On the field, the erosion focus has been in locating and mapping with GPS, as well as to determine the assessment of the degraded areas. Also soil and sediment samples were collected. In the laboratory, morphology, soil texture and clay mineralogy analyses have been done (Lemos & Santos, 1996; Embrapa, 1997). The soil samples have been spread in trays for complete air drying. After drying, they have been weighed and directed for study of the morphologic characteristics (Lemos & Santos, 1996). The analyzed characteristics are air-dry

and moist colour; soil structure; dry, moist and wet consistence; amount and size of macropores, presence or absence of coats and roots. Later, they have been pulverized for separation of the samples fractions (gravels and fine land dry to air) using 2mm and 20mm sieves.

The texture analyses have been carried out by pipette method according to Embrapa (1997). For identification of clay minerals, the x-rays difraction method was adopted according to Embrapa (1997), which proposes the separation of the clay fraction, carried out according to the pipette method with sodium hydroxide; preparation of glass blade with pasty clay, desiccated to the ambient temperature; and difratometer analysis. The difratograms have been interpreted according to the corresponding reflections to the angstrons minerals values.

Two initially identified gullies of Castelão and Sacavém (Figure 1) have been monitored by photo-interpretation and stakes, according to the described method by Guerra (1996). Stakes are fixed around of gullies; a Brunton compass and a meter are used to obtain three measurements taken from each stake to the gully border. Through this monitoring procedure, it is possible to determine the speed and the direction towards which the gully is retreating. Tables and diagrams are done, and demonstrate the advance of the erosion in these areas, as figures 4 and 5 demonstrate.

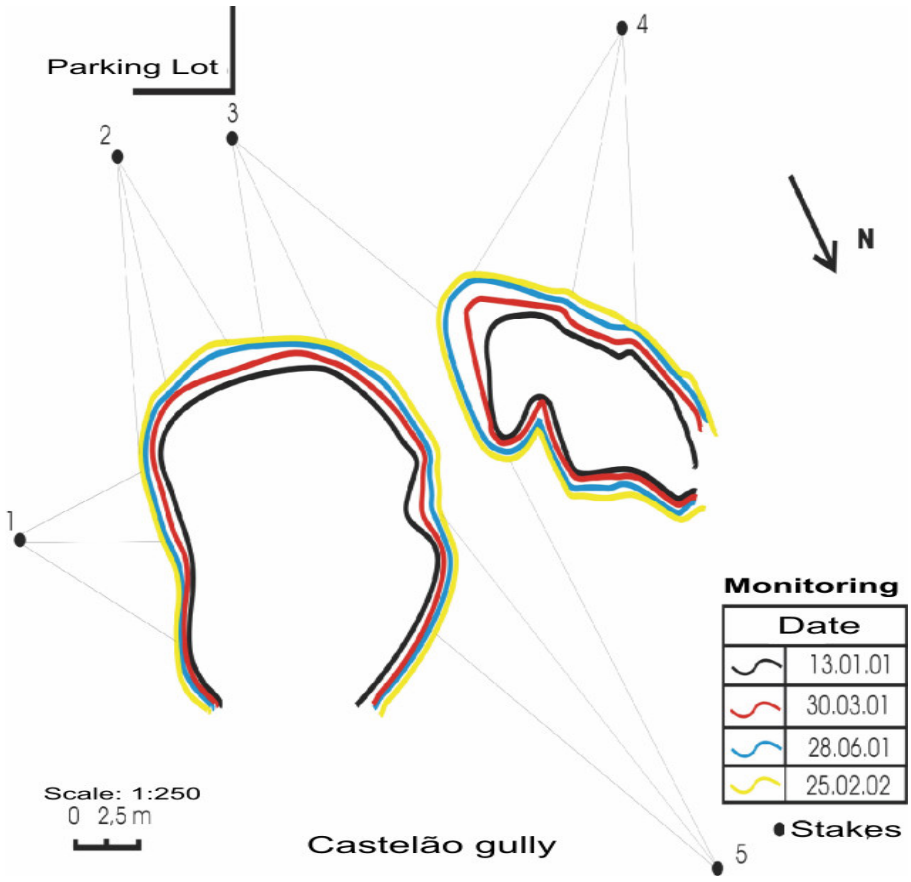

Figure 4: Diagram of Castelão's gully monitoring (Mendonça, 2003).

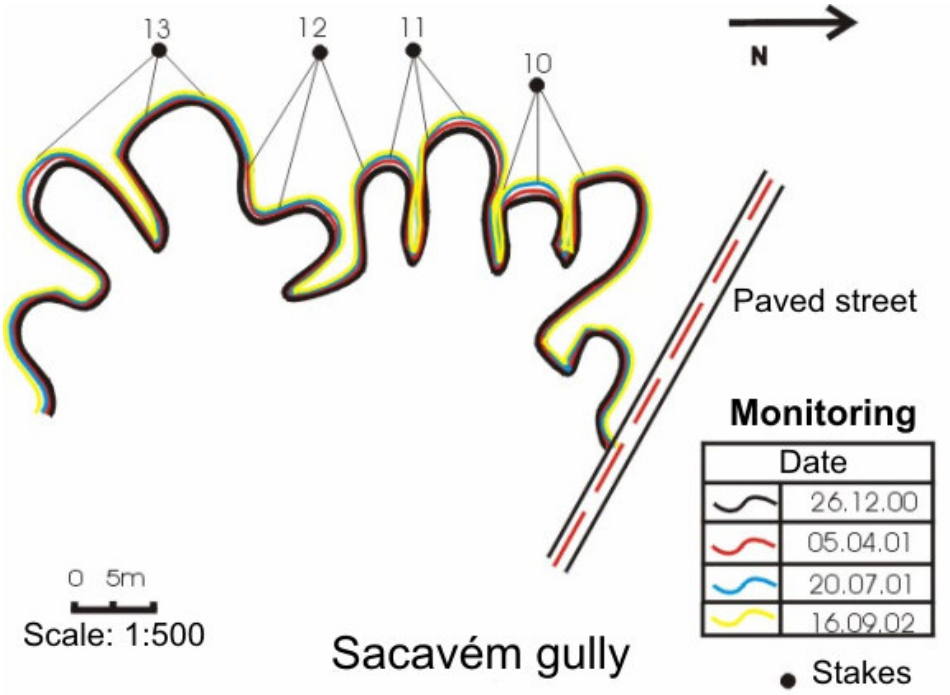

Figure 5: Diagram of Sacavém's gully monitoring (Mendonça, 2003).

RESULTS AND DISCUSSION

The preliminary results (Table 1) of the analyzed samples demonstrate that the soils and the sediments have in common clear colours that suggest low organic matter contents; block-type peds, exception done to granular peds for A's Parque Estadual and Apedal's Sacavém; coats absence; high sand contents, over all fine sand. The clay contents are very low, with exception of Parque Estadual's B horizon. In this point it was identified soil horizon differentiation, and being found a B horizon, lower and more reddish than the superficial and darker A horizon.

Table 1: Depth, morphology and fractions of soil and sediment samples

Results / Samples		*Castelão*	*Ponta d`Areia*	*Parque Estadual A*	*Parque Estadual B*	*Sacavém*
Collection depth in cm		150	6	5	15	160
Morfology	Dry Colour	5YR5/8	7.5YR7/6	10YR4/4	10YR5/8	10YR6/6
	Moist Colour	2.5YR4/6	5YR5/8	10YR3/3	10YR4/6	7.5YR5/6
	Soil Structure	Fine weakly subangular blocky	Coarse strongly angular blocky	Medium strongly granular	Fine moderately angular blocky	Apedal

	Dry consistence	Soft	Lightly hard	Hard	Lightly hard	Loose
	Moist consistence	Very friable	Very friable	Very friable	Very friable	-
	Maximum stickiness	Non plastic non sticky	Moderately plastic, Moderately sticky	Slightly plastic, slightly sticky	Very plastic, very sticky	Slightly plastic, slightly sticky
	Macropores	Many pores, very small	Few pores, very small	Common, very small	Common, very small	-
	Coats	Absentee	Absentee	Absentee	Absentee	Absentee
	Roots	Absentee	Very fine, few, fibrous	Fine, commom, woody	Very fine, few, fibrous	Absentee
Fractions (gram for kilogram)	Gravel	-	15,83	115,42	4,0	-
	Coarse Sand (0,2mm -2 mm)	402,44	200,60	216,8	91,40	25,36
	Fine Sand (0,053mm-0,2mm)	491,00	563,20	380,60	213,40	456,80
	Silt	62,60	106,20	243,60	328,20	460,80
	Clay	44,00	130,00	159,00	367,00	57,00

Also it has a well marked differentiation in texture horizons, between B and A horizons of the Parque Estadual's soil gully. On the gully head, erosion does not go deep beyond the B horizon, while that to the downstream shows a deepening that reaches claystones and schists, situated below the B horizon. In this case, the texture differentiations found on the profile exert control on the local erosive processes.

In the other collected points, the pedogenesis was not confirmed, being observed in profile, from the top to the basis of the gullies: stratificated sedimentary packages, in the Sacavém's specific case; a great undifferentiated deposit, sedimentary coastal sandy, for the case of Ponta d'Areia; and a colluvial deposit or embankment in Castelão's gully. Sacavém's gully, biggest and deepest over the four analyzed, presented the biggest content of silt and the minor clay content amongst all the collected samples, while that Castelão's and Ponta d'Areia's evidences have bigger sand contents.

The x-rays difraction was carried out on the clay fraction in three conditions, warm, with glycol and natural (Jackson, 1979), and the results are being presented in Table 2. The kaolinite was identified by reflections 7,1 and 3,5Å. The smectite was identified in 14Å, is being suffered expansion for 17Å with glycol, and was being collapsed for 10Å when submitted to 500ºc. The ilite was characterized by the 10Å and 3,33Å reflections, remaining unchanged when adedd glycol. The ghoetite was identified by the 4,19Å reflection, and its structure was broken down when submitted to the heating.

Table 2: Clay fraction mineralogy

	Castelão	*Ponta d`Areia*	*Parque Estadual A*	*Parque Estadual B*	*Sacavém*
Mineralogy	Kaolinite predominance; goethite presence	Kaolinite predominance; goethite presence	Kaolinite predominance; secondary presence of smectite; ilite and goethite traces	Kaolinite predominance; secondary presence of smectite; ilite and goethite traces	Kaolinite predominance; secondary presence of smectite; ilite and goethite traces

The material of Castelão's gully is stable considering the clay-minerals, presenting predominance in kaolinite. In this direction, the very sandy texture, without cohesion, plasticity and stickyness, corresponds more directly to the accelerated erosive process conditions.

Also the material of Ponta d'Areia presents a predominance of kaolinites, being therefore stable due to the clay-minerals. The great sand content, over all of fine sand, is an evidence of the erosive susceptibility of the area.

The samples collected in Parque Estadual evidence predominance of kaolinite and smectites in secondary amount, in both horizontes. In this sense, although being the least sandy samples amongst all the others, its observed that the soil is expandable, being susceptible to slippings.

Regarding Sacavém's sample, it shows the predominance of kaolinites and secondary presence of smectites. Added to the inherent instability to the expandable clay presented, it is noted conditions to the erosion due to the great silt content, slight aggregation and no structure of the material.

CONCLUSIONS

Considering the carried out studies, the soils and sediments of the area are, in general, arenaceous or very siltous, with slight aggregation, low organic matter content (identification tactile-appearance) and in some cases unstable and expandable due to the presence of 2:1 clays. These preliminary results lead to the conclusion that the study area is very susceptible to the erosive processes, mainly when submitted to the intervention of humans, without planning.

The area presents general favorable characteristics to the occurrence of erosive processes: concentrated rains; soil susceptibility to erosion; geologic formations consisting of inconsolidated materials; tabular and subtabulars tophills, with steep barriers displayed to the

erosive actions. Associated with these characteristics significant antropic interference is observed, through the inadequate soil use: deforestation, engineering constructions, real estate speculation, removal of material for the construction (gross sand, rock and clay), disrespecting the limits of rational use of the environment. The combined action of these factors has been accelerating the erosive processes evolution.

Monitoring of the erosive processes, carried out since January of 2001, demonstrates a recurrence of soil erosion where the vegetation was removed, on slopes between 5^{o} and 15^{o}, occupied by irregular population settlements without basic urban infrastructure, specially sanitation, rain pipes and paved roads. This irregular occupation by low income population generates precariousness in the conditions of population's life that evidences the lack of planning and predatory activities control, on the part of the authoritys and society. The erosion presentes itself more intense in those areas of recent demographic expansion, where areas with potential environmental risk can be found, provoking land degradation and silting up of the water bodies, patrimony losses and death risk.

Therefore, the understanding of the factors of the erosive processes, as well as the application of control measures and prevention are fundamental actions to the public security.

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