ERODIBILITY ANALISYS OF THE CAMORIM TRAIL – STATE PARK OF PEDRA BRANCA (PEPB-RJ) – BRAZIL

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INTRODUCTION

In the last years, there was a growth on activities linked to ecotourism in Brazil and therefore the protected areas became a great attraction to the people that seek this kind of leisure alternative.

The increase of the number of people looking for living in cohabition with nature and with different activities connected this sector, now makes a discussion about impacts caused by the visitation extremely important, mainly in protected areas.

The trails that are more used for recreational means, allows access to attractions and inner areas of protected areas and, in consequence, they possess considerable importance in the planning and management for public use. As defined by COSTA (2004, p.9): "*the trails should be creteriously located, planned, builted and managed in way to allow the conservation of the natural resources and the accomplishment of appropriated visitors contact*".

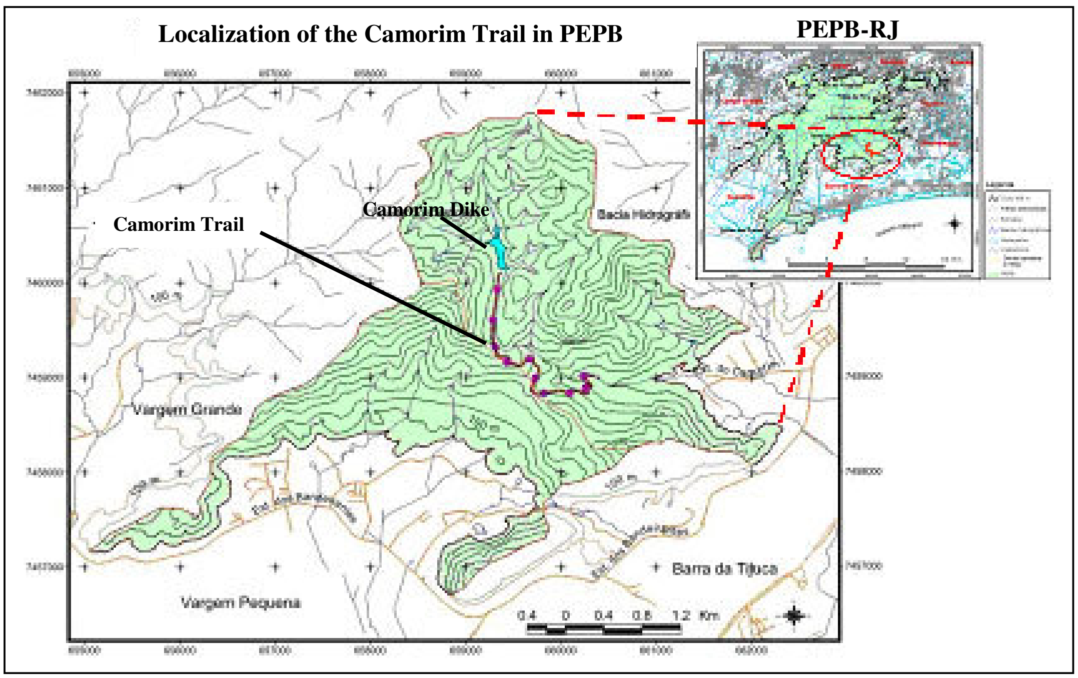
Some ecotouristic activities can produce negative impacts in trails, whose examples are trekking and walking accomplished by large groups of visitors, that unchain or increase erosive processes, depending on the form how they are driven. In reality, the great dilemma of those places, mainly those located in urban areas densely occupied, is the preservation of the ecological integrity, associated with potencial use of their resources, predominantly in interpretative and environment educational trails.

In this sense, the establishment of the ecotourism and recreational activities in trails inside protected areas, mainly in Rio de Janeiro city, should develop themselves based in detailed and effective planning, so much it concerns to control and mitigation of the negative impacts as growth of potential activities.

OBJECTIVE

In that context, the objective of the present paper is to diagnose and to evaluate some physical and chemical characteristics of soils, the factors that caused larger erodibility and which mechanisms can determine their compactness in one of the main trails of the State Park of Pedra Branca (Parque Estadual da Pedra Branca – PEPB) - the Camorim trail (Illustration 1). This trail has about 3,100 meters of extension and is inserted at the east slope of the Stadual Park of Pedra Branca (PEPB), located at west side of Rio de Janeiro district. It has a visitation structure that includes visitors notebooking and reception. During revitalization of the Park (in the last two years), it presented a continuous flow of visitors.

Illustration 1



So being, it became necessary to diagnose the physical and chemical structure of the soil at the trail, to check if their characteristics behave appropriately to intense visitation (the resistance of a trail surface to human travel-generated forces, like the pressure of the human foot) along the trail tread and their edges (the corridor of the trail).

A brief physical characteristic of the study area

Most of the Camorim trail crosses the hydrographic basin with the same name (with almost 7 km^2 of area). The drainage of 3th. order (based in the classification of STRAHLER, 1957) is very important, because it supplies some places of the Jacarepaguá depression.

The trail begins in 120 meters of altitude, where is located the 2nd headquarter of PEPB. The end is about 420 meters, culminating in a artificial dam (Camorim Dike) of the State Company of Waters and Sewer (CEDAE).

The area across the trail has a morphologic configuration of the hillsides, predominantly determined by the crack lines and brittles system with N50 - 60E direction. Geologically, it has the predominance of granites in most of the soil trail and its valley has the "V" form.

In previous studies accomplished by COSTA et al. (2002) and COSTA (2002), it was possible to determine a high potential of erodibility of the Camorim's River Basin, presenting mass movements and erosion processes unleashed during the rains of 1996, where they were possible to notice complex slope failure of great magnitude for the whole area of that basin.

The diversity of the use of the soil in the place, demonstrates the occurrence of significant stains of grass fields (some provoked by burning), agricultural cultivations (banana plantations) and the presence of human occupation (small farms, ranches and illegal occupation of medium/high level loint ownership and communities of low income) intermixed by woods of secondary Atlantic Forest, and present medium to high regeneration stage of grow.

In what concerns to soil types, we find three of them: the Red-Yellow Podzols, present in the first 1,000 m of extension, the Brunizem soil until 1,300 m and the Red-Yellow Latosols, going from 1,300 m until the last meters of the Camorim trail.

The steepness, in the toeslope is very significant, because it presents an average of 7 degrees (16%) until the middle of the trail and in the tipslope (final half of the trail) presents less of the half of that value, in other words, on average 3 degrees (7%) of steepness. It is worth while to emphasize that in 1,200 m of distance from the initial point of the trail, the steepness is one of the most highest, being around 15 degrees (33%).

METHODOLOGY

As methodology, the work was splited in three procedures as follows:

Chamber procedures

This stage of the work consisted of the accomplishment of thematic digital maps, through geoprocessing tools (using Geoprocessing Information System – GIS, Arcview 3.2a software) and cartographic bases.

It based on the preparation of digital bases, adjustments of the trail plan drawing and accomplishment of thematic maps.

A) Elaboration of Thematic Basin Map (Map 1 and 2):

This map was made, based on: (1) the delimitation done by the Rio Águas Foundation; (2) the digital Countor Map of Pereira Passos Institute (IPP) - 1999 and (3) the Basins Map of PEPB, accomplished by COSTA (2002).

Later, it was made the space cutting of the Camorim River Hydrographic Basin.

B) Elaboration of the Trails Thematic Map (Maps 1 and 2):

- The recognition of the trail was made by using the digital Countor Map in the scale of 1:10.000 UTM (IPP, 1999).
- The trails was evaluated in the field and other relevant aspects were marked in the digital base of the Camorim River Hydrographic Basin, such as: notable points, hydrography, main accesses (tracks, roads and highways), bifurcations and variants of the main trail and the location of the 2^{nd} headquarter of PEPB;
- It was made adjustment and updating of the plan of the trail using the digital base, starting from the recognition in the field, through the use of a manual navigation GPS (Garmin 12 XL).

C) Elaboration of the Thematic Slop Map (Map 1):

The map of steepness was accomplished through the software Arcview 3.2a (module Spatial Analyst), using the level curves (intervals of 10 meters) of the digital Counter Map of the IPP (1999) in the scale of 1:10.000 UTM.

For the sloping map, the following classes were considered:

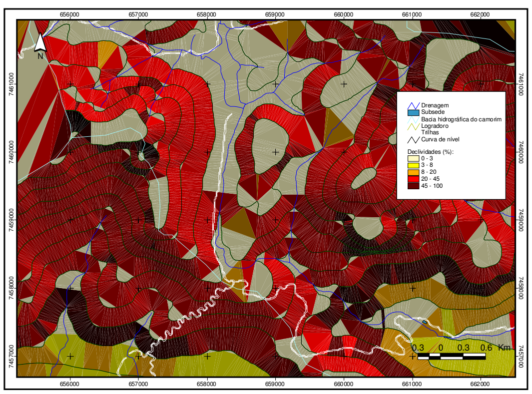
Interval of % (declivity)	Sloping classes	Characterization
< 3	Table relief	Surface of lessen wavy or horizontal topography, where the unevennesses are very small.
3-8	Softly wavy relief	Surface of topography little moving, consisting by set of hills and/or hillocks, presenting soft gradients.
8-20	Wavy relief	Surface of topography little moving, consisting by set of hills and/or hillocks, presenting accentuated gradients.
20-45	Strong wavy relief	Surface of topography put into motion, formed for hilllocks and/or mounts, with strong gradients.
> 45	Mountainous and scarped relief	Surface of vigorous topography, with predominance of an accident forms, usually constituted of mounts, mountains, massifs and mountainous alignments, presenting relatively great unevennesses and strong and very strong gradients, with valley-bottom.

Font: Adaptation from DE BIASE (1970) and based in LEMOS & SANTOS (1996).

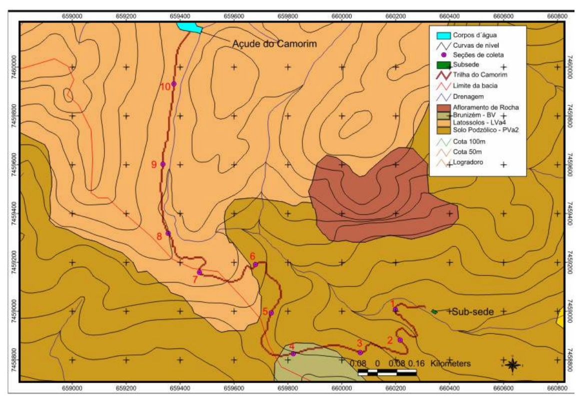
D) Elaboration of the Thematic Map of Soils (Map 2):

The digital letter of EMBRAPA was used (1980), in the scale of 1:50.000 UTM, that suffered updating for the Brazilian System of Soils Classification[1]. The study area was mapped in the digital base, through Arcview 3.2a.

MAP 1



MAP 2



Field procedures

A) To determine the sampling units in the trail:

The accomplishment of the field work was made by definition of sections (sampling units) in the Camorim trail. It was divided, along the extension, in 10 sections of 300 meters equally spaced. The sections extension was defined, taking as base 10% of the total extension of the trail (TAKAHASHI, L. Y., 2001).

It was used, as sampling unit, each point of the section (inernal part of the trail, its bed). The respective surrounding (right and left edge), where soil samples were collected.

[1] In: EMBRAPA, http://www.cnps.embrapa.br/sibcs/index.html, site visited in december of 2004

B) To determine the compactness of soil:

To evaluate the mechanical resistance of the superficial layer of the soil to penetration, it was used, in same places of collection of soil samples, the so called **Lang Penetrometer**[1] equipment. The reading of the equipment is made in inches, whose data were converted to Kgf/cm^2 (Table 1).

Table 1: Penetrometer of Lang Convertion

Soft		Medium		Litle-hard		Hard	
Inches	**Kgf/cm^2**	**Inches**	**Kgf/cm^2**	**Inches**	**Kgf/cm^2**	**Inches**	**Kgf/cm^2**
1	3,6	**8**	28,32	**17**	60,94	**19**	68,1
2	7,2	**9**	31,55	**18**	64,5	**20**	71,7
3	10,8	**10**	34,77				
4	14,4	**11**	38				
5	17,96	**12**	41,87				
6	21,53	**13**	45,75				
7	25,09	**14**	49,62				
		15	53,5				
		16	57,37				

Font: Adapted by COSTA, V. C. da (2005), based on MAGRO (1999).

It was made five readings in the layer (tread) of the trail, and two readings in each edge, to obtain an average of the resistance for each section of sample collection (MAGRO, 1999).

C) To determine the soil properties:

For the collection of a partial deformed soil, it was used an equipment called “Kopecky Ring”, according to EMBRAPA (1998) method, besides collected samples of rude soil, because the samples have to be analysed in laboratory.

Laboratory procedures

The physical and chemical analyses were accomplished in the Laboratory of Physical Geography (LAGEFIS) of the Geography Department in the State University of Rio de Janeiro (UERJ).

HARDLEY et al. (1985, in MORGAN, 1986) emphasized the importance of erodibility[2] in the soil properties as being the main factor in the prediction of the erosion and in the planning of the ground use.

[1] This equipment has an iron point (with nearly 10 centimeter of length) which is introduced in the topsoil until its base to measure the soil compactation.

[2] The soil erodibility is a parameter that allows evaluating of the resistance of the soil erosion. MORGAN (1986) defined erodibility as "*the resistance of the soil to be removed and transported*".

Several indicators of soil properties affect the soil erosion, among them we highlighted in this work: texture classes (grain-size distribution), bulk density, porosity, organic matter and pH (H^2O and KCl).

OBTAINED RESULTS

The results obtained with the analyses accomplished in the sections, along the whole Camorim trail, were:

A) Concerning to compacting (the penetration resistance) process of the soil.

The result of the soil penetration resistance is a good indicator for the evaluation of the trampling in the trail tread effects and to compare them with the values found in their edges. In Table 2 we observe that the average soil penetration resistance in the tread of the trail is superior to 57 kgf/cm^2, that denotes a larger compacting process, when compared to average found in the left and right edge of the trail (from 25 to 32 kgf/cm^2).

Table 2: Soil Penetration Resistance Data from the Camorim Trail

Section	Soil type	Trail Tread (Kgf/cm^2)	Compaction Level of the Trail Tead	Left edge of the Trail (Kgf/cm^2)	Compaction Level of the Left Edge	Right Edge (Kgf/cm^2)	Compaction Level of the Rigth Edge	Medium of the sections Kgf/cm^2	Medium Compaction Level of the Trail
1	Red-Yellow Podzols	57,37	Medium	34,77	Litle-Hard	28,32	Litle-Hard	34,77	Litle-Hard
2	Red-Yellow Podzols	49,62	Litle-Hard	28,32	Litle-Hard	38	Litle-Hard	38	Litle-Hard
3	Red-Yellow Podzols	64,5	Hard	38	Litle-Hard	21,53	Medium	38	Litle-Hard
4	Red-Yellow Podzols	53,5	Litle-Hard	21,53	Medium	17,96	Medium	21,53	Medium
5	Red-Yellow Podzols	64,5	Hard	25,09	Medium	21,53	Medium	25,09	Medium
6	Red-Yellow Podzols	57,37	Litle-Hard	28,32	Litle-Hard	31,55	Litle-Hard	31,55	Litle-Hard
7	Brunizem	57,37	Litle-Hard	25,09	Medium	17,96	Medium	25,09	Medium
8	Red-Yellow Latosols	60,94	Hard	45,75	Litle-Hard	28,32	Litle-Hard	45,75	Litle-Hard
9	Red-Yellow Latosols	57,37	Litle-Hard	31,55	Litle-Hard	14,4	Soft	31,55	Litle-Hard
10	Red-Yellow Latosols	60,94	Hard	41,87	Litle-Hard	25,09	Medium	41,87	Litle-Hard
Medium		57,37		31,55		25,09			
Desviation Pattern		4,63		7,91		7,20			
Median		57,37		31,55		25,09			
Minimum		49,62		21,53		14,4			
Maximum		64,5		45,75		38			

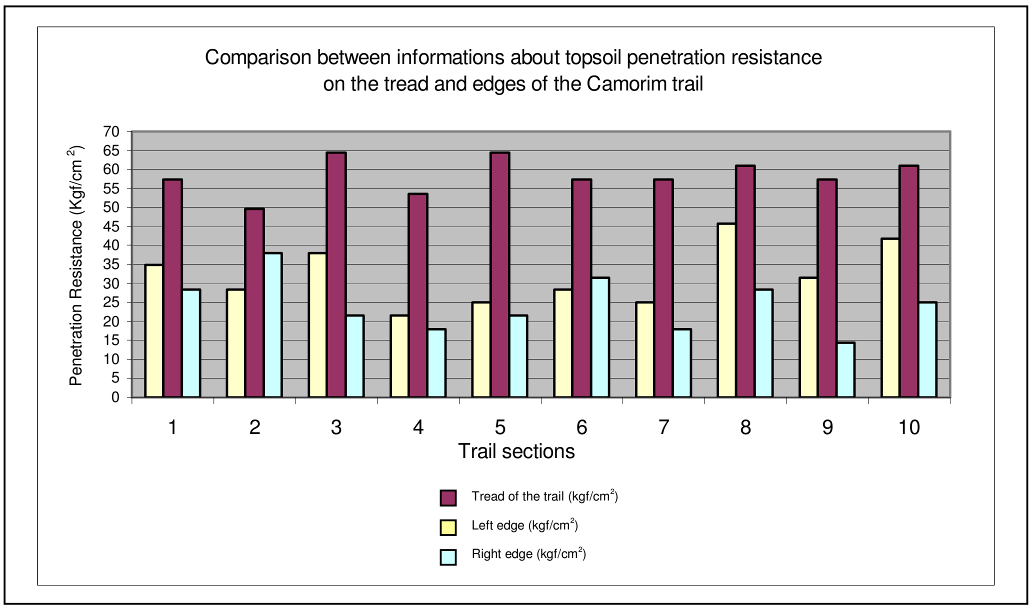
Font: Adapted by COSTA, V. C. da (2005), based on field informations.

In Graph 1, it is observed that the sections 3, 5, 8 and 10 present the largest indexes of soil penetration resistance.

The tread of the trail in sections 3 and 5, that are located in the downhill slope, presents exposed soil occurrence (without litter) and rocky blooming in great amount, that provides a larger compacting process in those places.

In the 8 and 10 sections, that are located in the high hillside, presents shallow soils, more narrow in the tread of the trail (in some points between 2 and less than 1 meter width), provoking visitors continuous passage on the same place and, then, facilitating the compacting process.

Graph 1



B) Concerning to soil properties:

- Analysis of the Bulk Density X Porosity

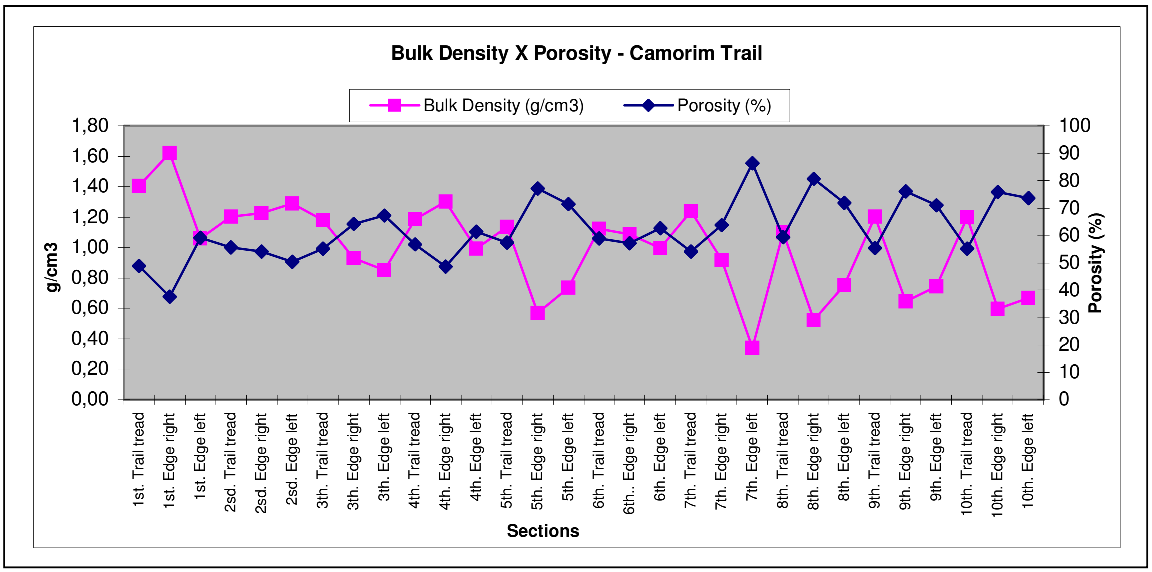
The bulk density is to evaluate the compacting process and it can vary according to the type of soil. According to JOAQUIM (1979) and JORGE (1986), in organic soils (with less than 2% of organic matter), the variation is from 0.20 to 0.30 g/cm^3 and from 0.60 to 0.80 g/cm^3, depending on the porosity of the soil (from 60 to 80%), because, it is known that the bulk density is inversely proportional to the porosity.

In mineral soils, it can have a variation of bulk density from 1,10 to 1,38 g/cm^3 (in soils with porosity between 40 to 60%) and from 1.42 to 1.75 g/cm^3 (in soils that have 35 to 50% of porosity).

The increase of the bulk density in the Camorim trail, therefore, should follow the variation present in mineral soils. The values that follows that tendency, begin to be visible in sections 1 and 7 (Graph 2) in the tread of the trail where, respectively, we found 1.40 g/cm^3 and 1.24 g/cm^3 and, consequently, a low porosity (48.8 and 54.1%). There are evidences of a compacting process in those sections, meaning that the trail should be monitored (new samples of soils should be collected again) in the future, to observe if there will be a more significant increase of the bulk density and porosity of the soil.

High values of bulk density contribute to a smaller infiltration of the rainfall, consequently they increase the sheetflow and accelerate the formation of rill erosion and runoff-ruts in the topsoil.

Graph 2



- Analysis of the Texture Classes (Grain-size distribution) X Organic Matter X pH

The parameters of texture classes of soils were made in agreement with the percentages of sand, silt and clay, defined in CURI et al. (1993).

In the present study, it was observed that, in just one section of the trail, the percentage of the clay fraction is larger than the sand and silt fraction together (section 5 - 50%).

It was noticed in 5 sections: 1 (76%), 2 (74%), 4 (70%), 7 (72%) and 10 (78%), a larger percentage of sand, added to silt.

In the tread of the trail of six sections (2, 4, 6, 7, 8 and 9), occurred clay loam textures (with higher percentage of rude particles of sand than of clay), in other words, they are soils of low capacity of water retention, cohesion and capacity of cations exchange, however high capacity of air circulation with larger percentage of macroporosity (interparticle space) and detachability.

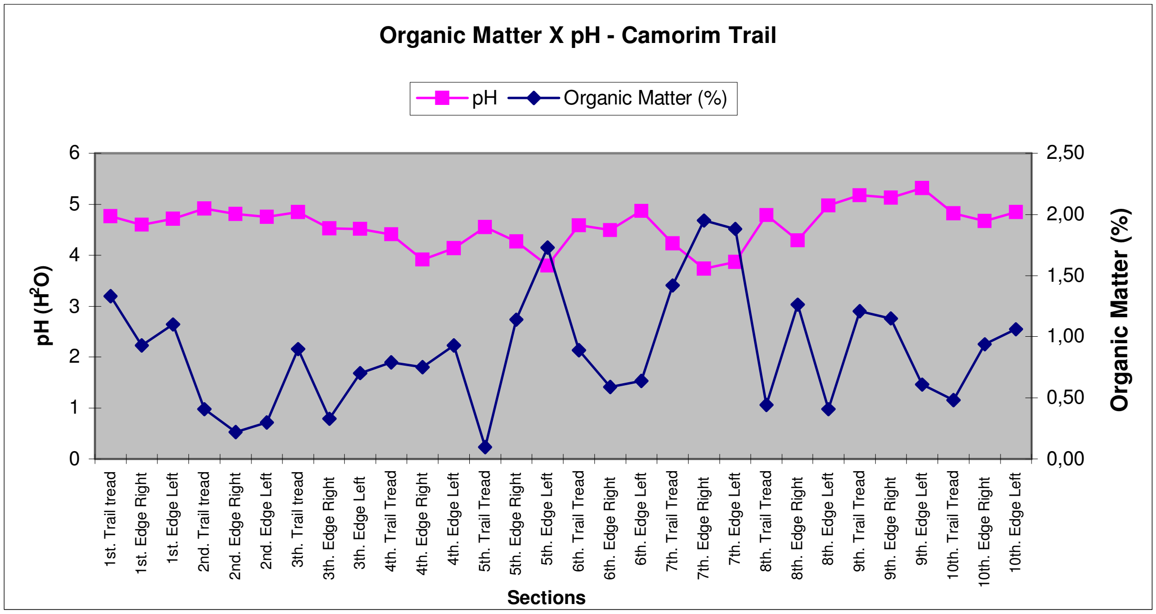
The percentages of sand, silt and clay should be taken into account together with other soil properties, because those fractions can be affected by other elements, as the organic matter. As the organic matter decreases the crack of the aggregates increases and crusts are formed in the surface of the soil, increasing the compacting process, hindering the penetration of the water, restricting the movement of the fine particles and facilitating the runoff. According studies of MORGAN (op. cit.), there are some cases in which soils with sands and silts present smaller percentages of organic matter, lower than 2.0%, indicating low stability of aggregates (GUERRA, 1998:156).

Camorim trail has four sections lower than 0.5% and six sections from 0.5% to 2.0% of organic matter. In five sections, commented previously in the texture classes (with larger percentage of sand fraction), it was possible to verify that (section 2 - it varies from 0.2 to 0.4% and section 10 - from 0.5 to 1.0%), they are the ones that possess smaller percentage of organic matter.

The ones that present larger percentage of organic matter are the sections: 1 (0.9 to 1.3%), 4 (0.7 to 0.9%) and 7 (1.4 to 2.0%), probably due to the amount of vegetation and roots in the edges and of larger quantity of litter contribution. Particularly, in the sections 4 and 7 the concentration is larger, because the topography of the place in the hillside forms small "tables" of sedimentary deposits (for superficial drainage) that comes from other areas and side slope.

The pH of the Camorim trail, was shown strongly acid. We can notice, in the Graph 3, that the very acid indexes (strip below 4 for the pH is a limit that is considered for mineral soils) stand out in all of the sections. In the section 7, where we detached organic matter and high porosity (2%), the pH varies from 3.9 to 4.4 (in the edges and the tread of the trail), denoting a probable lack of nutrients absorption, ideal or normal for the growth of the plants.

Graph 3



- Analysis of Soil Erodibility (factor K)

Using the texture classes and organic matter data, it was possible to determine the soils erodibility factor (K) from the Camorim trail.

In present work was opted to use the MITCHELL & BUBENZER methodology (in KIRKBY & MORGAN, 1980) to determine the interpretation of soil erodibility classes (factor K), where the authors associate textural classes to the content of organic matter (Table 3):

Table 3: General Magnitude Indicators of Erodibility Factor (K)

Textural Classes	Organic Matter (%)		
	< 0.5 K	0.5 – 2.0 K	2.0 – 4.0 K
Sand	0.05	0.03	0.2
Loamy sand	0.12	0.10	0.8
Silt	0.60	0.52	0.42
Sandy-loam	0.27	0.24	0.19
Silty-loam	0.48	0.42	0.33
Loam	0.38	0.34	0.29
Sandy Clay-loam	0.27	0.25	0.21
Silty Clay-loam	0.37	0.32	0.26
Clay-loam	0.28	0.25	0.21
Clay Silty	0.25	0.23	0.19
Clay loam	0.14	0.13	0.12
Clay	0.13 – 0.29		

Font: Mitchell & Bubenzer *in* Kirkby & Morgan (1980)

According to CARVALHO (1994), in intervals of K values smaller than 0.15, the erodibility is low; from 0.15 to 0.30, it is medium, and larger than 0.30, it is high. Using this data, it was found the following results expressed in Table 4:

Table 4: Classes of interpretation values of K factor – Camorim Trail

Sections (tread of the trail)	Intervals of K values (t ha year tm^{-1} ha^{-1} mm^{-1})[1]	Interpretation Classes
1	0.25	Medium Erodibility
2	0.28	Medium Erodibility
3	**0.34**	**High Erodibility**
4	0.25	Medium Erodibility
5	0.13 a 0.29	Medium Erodibility
6	0.25	Medium Erodibility
7	0.25	Medium Erodibility
8	0.28	Medium Erodibility
9	0.25	Medium Erodibility
10	0.27	Medium Erodibility

Font: Adaptation of Carvalho (1994).

It was observed, in table 2, that in all sections (in the tread of the trail), the erodibility factor is the same or superior to 0.25, that is, the whole trail is characterized by presenting high average of soil erodibility.

However, it is approppriate to emphasize that such results are indirect methods that are destined to an immediate calculation use of the Universal Soil Loss Equation (USLE[1]), according to BERTONI & LOMBARDI NETO (1990).

FINAL CONSIDERATIONS

The present study demonstrated that there is pressing need to intervention, in short and medium term, in Camorim trail due mainly to the compromising of the soil structure (narrowing of the tread of the trail, fall of trees, rill erosion and runoff-rots, loss of critical edge, among others).

The structural analyses of the soils was identified as an important tool to obtain erosive behavior of the trails. Besides that, the data registered by the erodibility factor (K), can allow, in future, more detailed studies, as example the USLE, to be accomplished with use of softwares of GIS.

The example of the Camorim trail, being in a protected area (PEPB), will allow the administration (State Institute of Forest - IEF/RJ) of the Park, the use of important informations as an instrument for maintenance and integrated management of the ecotourist activities.

[1] According to International Metric System. It´s more common to use the tons per acre per year in the USLE.
[2] The USLE was devoloped for agriculture with increasing use on forest land.

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