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SOIL EROSION ANALYSIS IN THE INFLUENCE AREA OF TIETÊ-PARANÁ HYDROWAY (TIETÊ BRANCH)

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ABSTRACT

The Tietê-Paraná Hydroway corresponds to 2.400 kilometers of navigable area between the Tietê and Paraná rivers, integrating six brazilian states: São Paulo, Paraná, Goiás, Mato Grosso, Mato Grosso do Sul and Minas Gerais. It stands from the municipality of Conchas in São Paulo State and ends in the lake of the Itaipu Hydroelectric Power Plant in Paraná State, comprising 1.642 km of major routes and 758 km of secondary routes.

The area of study includes six hydrological basins in the influence area of the Tietê-Paraná Hydroway particularly in its Tietê Branch, involving the territorial area of 225 municipalities which consist of 28% of the total number of municipalities and 23% of the total population of São Paulo State. Inside these basins there are some densely populated urban areas and the major industrial region of the inner portion of São Paulo State.

The main technical parameters used in the soil erosion analysis consists of: the natural soil erosion susceptibility of the terrains and the land use types, considering the effects of the land use in each particular terrain.

By using aerial photographs of 1972 and field investigation data of 1990, linear erosion incidences were mapped. A value of erosion density was achieved considering the number of linear erosions and the area of each hydrological basin.

The critical basins for the occurrence of linear erosion were obtained by considering the value of erosion density and the natural erosion susceptibility of the terrains. The main critical areas present high and very high erosion susceptibility, and great number of linear erosion processes.

It was also possible to identify the municipalities with great potential to generate impacts to the Hydroway by considering: the urban erosion condition, number of linear erosions in rural areas and the classes of high and very high susceptibility existing in the municipal area. The silting up of sediments in the border of reservoirs in the main channel of navigation and in transposition points (bridges, landfills, terminals and others) are the major impacts due to erosion processes in the region.

Key-Words: erosion; Tietê-Paraná Hydroway

INTRODUCTION

This work is part of a major project conducted by IPT (Technological Research Institute) for the State of São Paulo Government, with the objective of produce a Data Base of information concerning environmental and infra-structure aspects, in order to help the management of the Tietê-Paraná Hydroway and the social and economic development of its influence region, as well as to help the formulation of public policies (IPT, 1999c).

The Data Base was structured in themes and sub-themes, based on the concept of environment adopted by IPT and adapted to the needs of the client. The technology of Geographical Information System (SIG) was used to organize the digital data. The Data Base is available for use in the local network of IPT and it has an architecture which facilitates its posterior migration for WEB.

The Tietê-Paraná Hydroway is one of the major five hydroways in Brazil. It comprises 85% of its navigation routes in reservoirs, consisting of 13 dams and 10 floodgates in the area between the reservoirs of Barra Bonita and Itaipu (Figure 1).

The modality of hydroway transportation is rather worth-while especially considering the environmental gains (less physical interventions, low energy consumption and lower emission of pollutant gases to the atmosphere), costs (of construction, operation, value of freight) and durability.

The main transported freights are solid grains (soy and corn) which comprehends 70% of the total; general goods (especially sugar-cane) corresponding to 20% of the total; and liquid matters (especially alcohol) corresponding to 10% of the total.

The study area corresponds to the Tietê Branch of Tietê-Paraná Hydroway, which extends from Barra Bonita Hydroelectric Power Plant (including part of Piracicaba river) to Ilha

Solteira/Jupiá Hydroelectric Power Plant (including the drainage channel of Pereira Barreto). It comprises the area of six major hydrological basins (Unidades de Gerenciamento de Recursos Hídricos - UGRHIs): Baixo Tietê, Piracicaba/Capivari/Jundiaí, Sorocaba/Médio Tietê, Tietê/Jacaré, Tietê/Batalha and São José dos Dourados. Some of remarkable cities for business investiments in Brazil are inside the study area, like Campinas, Ribeirão Preto, São José do Rio Preto, Bauru, São Paulo, Piracicaba, among others. Regional development plans involving the fixation of industrial poles and tourism in the region have also been undertaken.

In terms of physical environment the area extends along distinct geomorphological zones: Província do Planalto Atlântico, Depressão Periférica, Cuestas Basálticas and Planalto Ocidental Paulista. The part of the area corresponding to the Planalto Atlântico is mainly characterized by high plateaus of pre-Cambrian crystalline rocks; the Depressão Periférica Province corresponds to a 50 km width belt of hills and gully slopes; the Cuestas Basálticas Province is one of the most remarkable feature of São Paulo State relief, due to the abrupt scarps and table plateaus in the area of contact between the sedimentary formations and the basalt of the Paraná Basin, in the limits with the Depressão Periférica; the Planalto Ocidental Province covers great part of São Paulo territory and presents a shy relief composed predominantly by hills.

OBJECTIVES

This paper aims to present the studies concerning the occurrence of erosion processes according to the natural susceptibility of terrain and the effects of land use. The most critical areas to linear erosion process are identified together with the major corresponding impacts.

Such studies were conducted especially considering the process of linear erosion responsible for the most serious and the immediate impacts to the water resources and social and economical damages.

WORKS UNDERTAKEN

Erosion process is one of the main geological process occurring in the study area. Conceptually, hydric erosion is the process of disaggregation and transport of particles of soil or fragments and particles of rocks, by the combined action of gravity and water…(DAEE/IPT, 1990). The erosion can be “normal” or “man-made” according to the intensity of the process. Generally, the man-made erosion has an intensity of terrain degradation superior to the natural soil recuperation.

The erosion can occur differently according to the intensity of the process: the **laminar erosion** is characterized by the diffuse, not concentrated runoff and transport of the soil; **linear erosion** is characterized by the concentrated runoff of water with the incisive remotion and transport of the soil.

The main types of linear erosion are the following:

a) **Furrow**: consist of small ruptures in the surface of terrain, generally related to cattle track and exposition of soil due to ground motion;

b) **Ravine**: is formed by the action of concentrated superficial runoff and by erosion mechanisms involving mass movements represented by small slidings in the lateral slopes caused by undercutting of their bases due to superficial runoff in its interior, provoking its enlargement;

c) **Gully**: is formed by the deepening of ravines and interception of water table where complex processes can be observed (piping, sand liquefaction, lateral landslides, superficial erosion) due to the concomitant action of surface and subsurface water. This type of erosion process can reach great dimensions, producing various environmental impacts in the surrounding areas and in drainage downstream, affecting seriously the land use in such areas.

In this work, the analysis of erosion susceptibility of the study area was done following the results of Erosion Map of São Paulo State (IPT, 1995) and field works conducted. This map presents distinct units for erosion process according to geological aspects, relief, and soil types, showing five classes of erosion susceptibility:

- **Very high (I)** - all the types of erosion described occur in this class. Laminar erosion is intense, furrows are common as well as ravines of various sizes frequently turning to gullies. More than 65% of São Paulo State erosions are placed in this class;
- **High (II)** - mass movements are the most common process in this class. Mud and block flows can occur in headwaters affected by erosion and heavy rainfalls. In landslide features intense erosion processes may be developed such as gullies;
- **Medium (III)** - ravines commonly occur in this class. When they reach the drainage or groundwater level they change into great size gullies. Laminar erosion and furrows also occur moderately;

- **Low (IV)** - laminar erosion occurs from moderate to intense way in the slopes. Furrows and ravines may rarely occur in the steeper part of slopes.
- **Very low (V)** - accumulation of sediments is the predominant process in this class, as well as undercutting of fluvial banks. Laminar erosion and furrows may occur with low incidence.

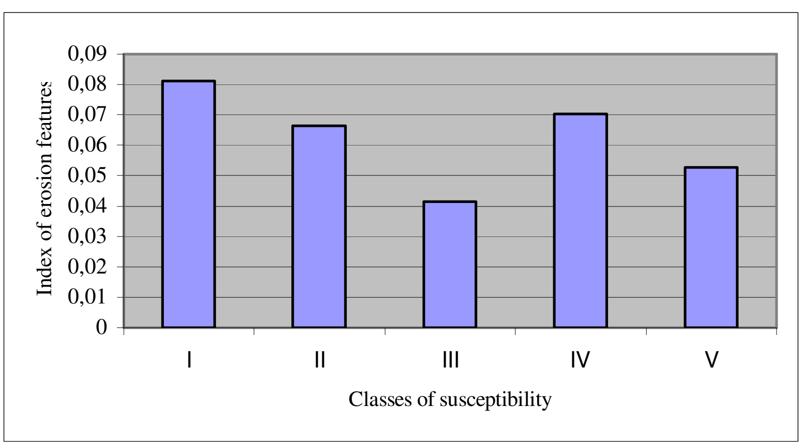
RESULTS

The area of study presents medium and high incidence of erosion features, due to the natural susceptibility of the terrain, which are more effective in the areas present inside the following geomorphological provinces: Planalto Ocidental, Depressão Periférica and portions of Planalto Atlântico.

The soils with sandy texture are more prone to erosion. Laminar erosion occurs intensively in any class of erosion susceptibility, while ravines and gullies are the main forms of erosion in the classes I, II and III, representing the most remarkable erosion processes (Table 1 and Graphic 1).

Classes of erosion susceptibility	Number of erosion features	Area (km^2)	Index of erosion features
I	1019	24.829,13	0,0812
II	245	14.272,56	0,0664
III	343	17.434,29	0,0415
IV	262	13.426,31	0,0702
V	14	1.117,86	0,0527

Table 1 – Distribution of erosion features by classes of susceptibility



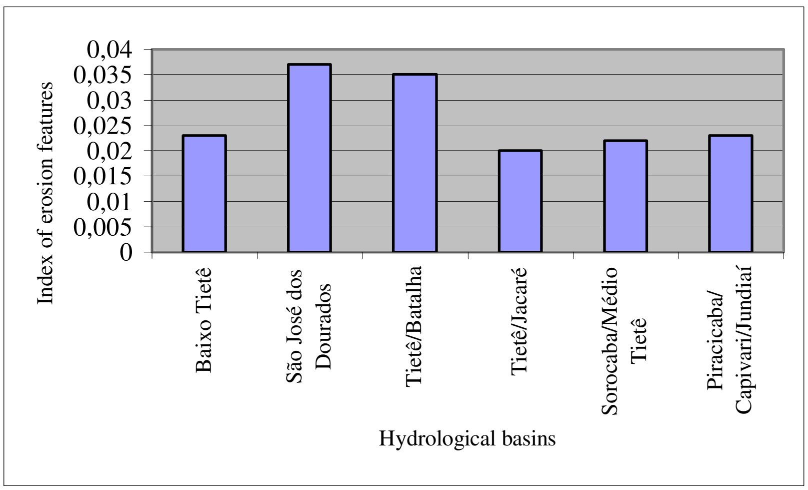
Graphic 1 – Index of erosion fetaures by classes of susceptibility

By using the historical cases and the occurrences of erosion in an area, it is possible to study its environmental condition. This analysis was undertaken to the hydrological basins in the study area in order to identify the most critical basins to erosion process.

These basins show great number of erosion features of linear type and present very high and high susceptibility (classes I and II) as can be seen in Table 2 and Graphic 2.

Hydrological basins	Number of erosion features	Area (km^2)	Index of erosion features
Baixo Tietê	360	15.688,94	0,023
São José dos Dourados	238	6.508,48	0,037
Tietê/Batalha	458	13.143,41	0,035
Tietê/Jacaré	237	11.866,24	0,020
Sorocaba/Médio Tietê	260	11.865,75	0,022
Piracicaba/Capivari/Jundiaí	332	14.242,31	0,023

Table 2 – Distribution of erosion features by hydrological basin.



Graphic 2 Number of erosion features by hydrological basin

After the study of the critical hydrologic basins it was possible to identify the most critical municipalities to erosion process as well. The municipalities which presented serious conditions concerning erosion process are listed bellow:

- Class I: Santa Bárbara D'Oeste, Sumaré, Ipeúna, Charqueada, São Pedro (Picture 1), Águas de São Pedro, Anhembi, Bofete and Botucatu;
- Classes II and III: Agudos, Bauru, Pirajuí, Balbinos, Itaju, Iacanga, Borborema, Taquaritinga, Cafelândia, Birigui, Araçatuba, Guararapes and Novo Horizonte.

Erosion problems are also manifested due to other kinds of land use forms such as highways, mining, agriculture. In this study, however, the impacts related to these kinds of use were not analysed.

Picture 1 – Gully erosion situated in São Pedro municipality
(Archive IPT)

FINAL CONSIDERATIONS

The impacts from erosion process in urban and rural areas can occur differently in terms of its intensity. Laminar erosion, commonly occurring in rural areas, is not so perceptible while occurring continuously by carrying out the most superficial horizon of soil. The problem of laminar erosion in agriculture can be detected by the loss of productivity in the rural area.

The impact of laminar erosion in rural areas can also be observed in the watercourses and water supply reservoirs due to the great amount of sediments contaminated by fertilizers and other chemical materials used in agriculture.

The damages directly caused by erosion are commonly of socioeconomic nature, and are referred to: loss of agricultural soil and productivity, destruction of civil works such as highways and roads, and also the destruction of houses and public equipments in urban areas.

The linear erosion in urban and rural areas causes a direct environmental impact due to the great amount of soil loss, the difficulty to recuperate the affected area, the negative visual impact and the silting up of dams and water supply reservoirs.

The presence of linear erosions such as furrows, ravines and gullies in urban areas is a difficult problem to solve. Those great erosion processes cause serious trouble to the urban development, especially by affecting the normal life of the population living nearby.

The recovering of those places affected by linear erosion generally requires great amount of investments. Other factor of loss is related to the degradation affecting the areas adjacent to the linear erosion feature.

The long term damage occurs intensively in the area, affecting water resources and the fluvial navigability of rivers. The silting up of sediments along the river channel due to sediments from erosion sources can also cause great damages and upsets. Especially in the case of the navigability of rivers, the impact of the silting up is a very serious damage.

The environmental impact due to silting up process is very clear in many parts along the Tietê river and its affluents (Picture 2). It can be observed vast deposits of sediments along river channels. Most of them are recent sediment deposits composed by unconsolidated materials caused by man-made activities and prone to be retransported to lower points of the drainage system.

Picture 2 – Silting up in Piracicaba river caused by erosion from Santa Bárbara D´Oeste urban area (Archive IPT).

Aiming to define mitigation and control works to face the problem of silting up, studies should be proposed to a more detailed and integral diagnosis of the actual situation involving the most prone areas to this process.

Quantitative and qualitative characterization must be done along the Tietê river in order to the proposition of prevention and mitigation measures.

Together with the studies regarding the silting up process also those works related to erosion must be conducted aiming the application of control works. The further works to be continued must be done in greater scales, with a focus on the most critical areas and using the hydrologic basin as the unit of analysis.

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