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MORPHOPEDOLOGICAL STUDY OF THE ARROIO GUASSUPI WATER BASIN, SÃO PEDRO DO SUL – RIO GRANDE DO SUL (RS): BASIS FOR UNDERSTANDING EROSION PROCESSES

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INTRODUCTION

Soil erosion represents one of the most serious environmental problems, jeopardising food production in terms of quality and quantity. It is, therefore, strictly linked to scarcity and starvation. Bertoni & Lobardi Neto (1990) point out that eroded lands have had their productive capacity reduced, making the struggle against erosion fundamental in some parts of the world.

In Brazil, around 600 million tons of agricultural soil are lost per year (BAHIA et al 1992). According to Infanti Jr & Fornasari Filho (1998), the phenomena related to erosion formation are caused by two main types of factors or agents: the anthropogenic type, such as deforestation, mining activities and ways of using and occupying the soil (agriculture, construction works, urbanisation, etc.), which precipitates the erosion process immediately or after some time; and the natural type, which will determine the intensity of the processes. In this group, we can highlight the rain, vegetation cover, relief, soils and bedrock.

When the erosion process takes place under natural or non-disturbed conditions, a permanent balance is established, and no greater damage occurs. However, when this balance is broken, erosion creates serious problems, not only in agriculture, by generating a gradual loss of productivity, but also in the management of water resources, contaminating them with sediment.

According to Fendrich (1997), this situation is deepened by the unsuitable management of land, which is due to the disrespectful and devastating action of men, as well as the lack of agricultural education programmes which could provide the grower with the knowledge to make better use of land and water.

In the face of this context, the goal of this research is to identify and to analyse, through the morphopedological approach, the relationship between soil, relief and bedrock in

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the Arroio Guassupi water basin, in order to diagnose and understand their connections with the erosion pattern, and, consequently, erosion susceptibility.

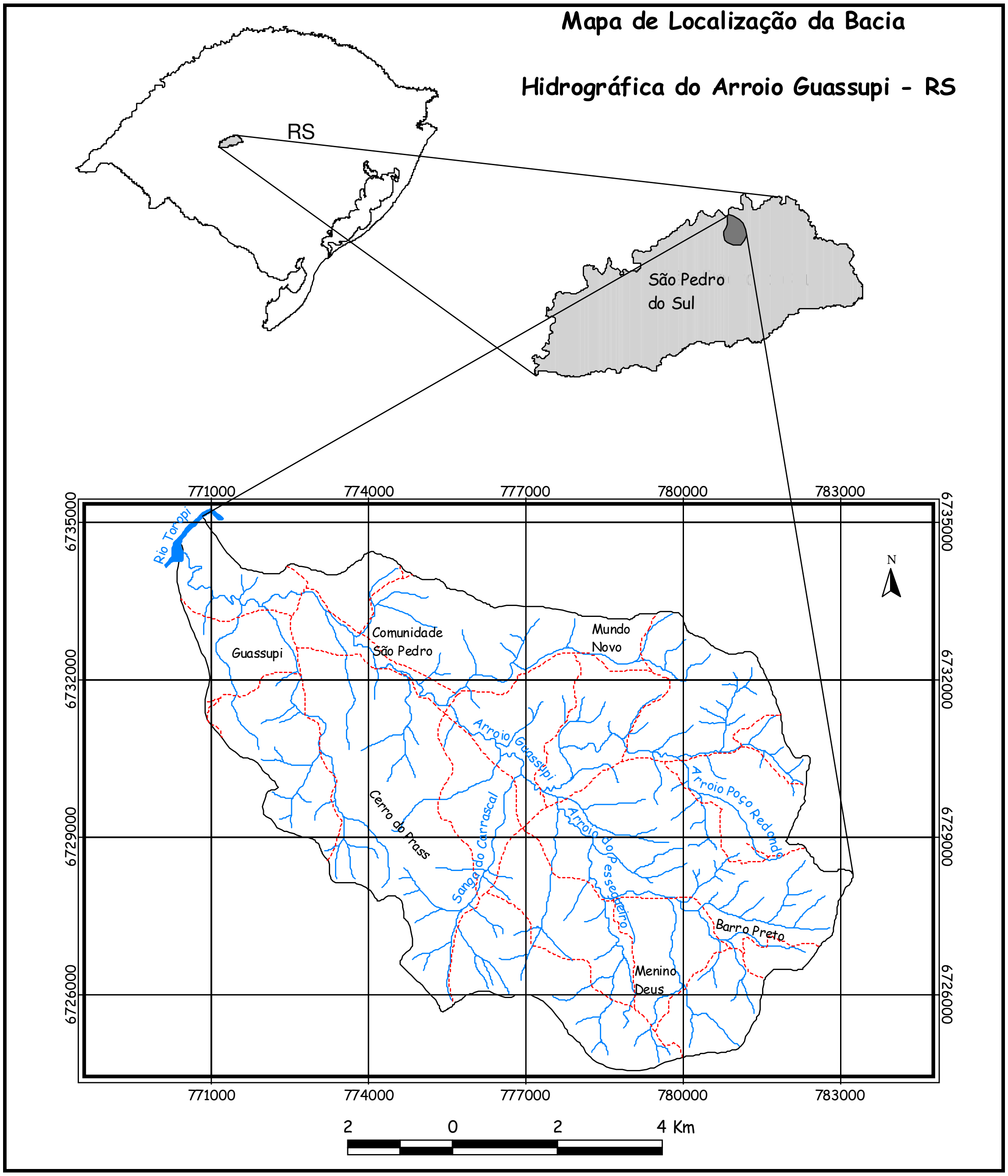
The studied water basin belongs to the municipality of São Pedro do Sul (Picture 1), in the centre of Rio Grande do Sul state - Brazil and placed within a transitional strip between the Central Depression and the Rio Grande do Sul Plateau (Rebordo). This basin was chosen as it is under the action of intense erosion processes, as is the large geomorphologic compartment that has its evolution connected to the retraction of its steep face caused by regressive erosive action.

With a 78.97 km^2 area, this basin is situated North of the municipality of São Pedro do Sul-RS. The geology of this area is basically comprised of two formations: Serra Geral and Botucatu. According to Köppen´s classification, the climate in the municipality, as well as in the water basin, is of Cfa type – subtropical always wet, with hot summers.

In relation to the soils, according to Klamt et al (2001), the four predominant types in the Rebordo area, as well as in the Arroio Guassupi water basin, are Alfisol, Inceptsoil, Gleysol and Neosol.

Different forms of relief comprise the geomorphology of this area. The lower part of the basin, with altitudes between 100m and 160m and declivity of 0% to 3% constitutes the alluvial plain, where the process of the accumulation of sediment is predominant. *Sharp - topped residual relief* can also be seen. Also known as witness hills, they are the remains of regressive erosion.

In the part with altitudes that vary between 160m and 340m and declivity of 12% to 45%, *concave and convex dissection forms* can be found. They are situated both on the left and right bank of Arroio Guassupi and represent a transitional relief, as when the relief is over 340m, the passage to the portion of higher altitude can be seen. They are the *flat-topped residual relief,* which are flat areas with declivity varying between 0% to 6%.



Picture 1 – Studied Area Location Map.

METHODOLOGY

In order to reach its stated goals, this research applies the methodology guide proposed by Castro & Salomão (2000) for the Morphopedological Compartmentation of the basin, with the level of treatment and modifications adapted to the reality of the studied area. Table 1 specifies the applied methodology guide in details.

TABLE 1 – Methodology Guide

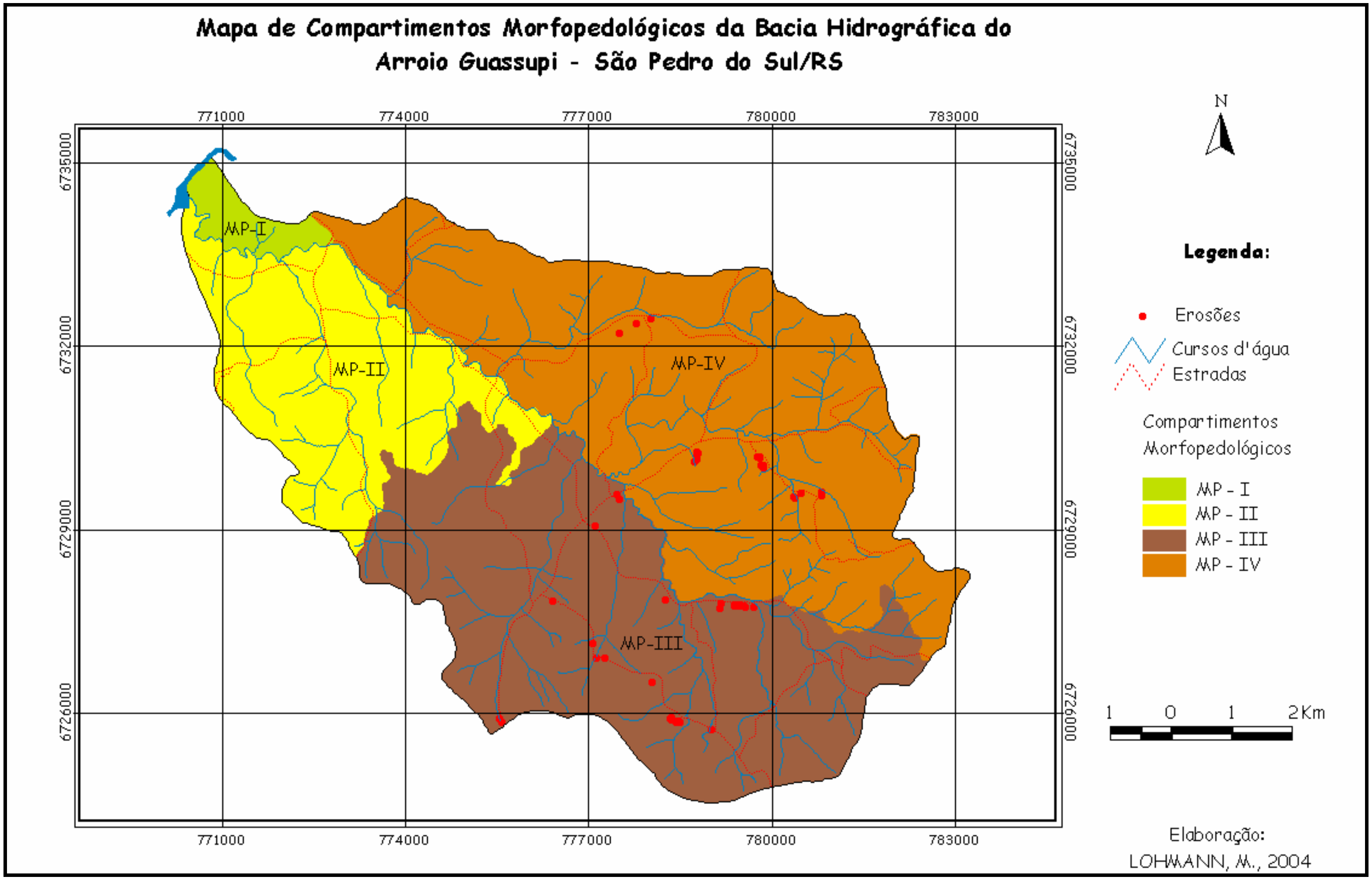
Levels of Treatment		Main Activities	Main Procedures
1st phase	Compartmentation Preliminary Morphopedological	• Creation of thematic maps of the studied area • Integrated thematic and analytic studies of the environmental features with field recognition.	• Superposition of thematic maps: geologic, types of soils and geomorphologic • Usage and occupation map; • Delimitation of morphopedological units (homogenous areas) • Preliminary scheme of the morphological units of the studied area;
2nd phase	Field Work	• Assessment of the cartographic material • Survey and morphological description of soils; • Mapping of erosion occurrences;	• Interpretation of the spatial relationship between soil-relief-bedrock and water behaviour; • Relationship between usage, occupation and management of soils, and the susceptibility to erosion;
3rd phase	Generalisation of results	• Systematisation of results by the identification of the relationship between erosion processes and morphopedological units.	• Cartographic representation; • Erosion occurrences map; • Morphopedological map; • Susceptibility map;

Source: Adapted from Castro & Salomão (2000).

RESULTS

Morphopedological Compartmentation

According to the methodology above, a morphopedological compartmentation map (picture 2) and a map of susceptibility to linear erosion in the Arroio Guassupi were created. Delimitation was created for four compartments that present singular characteristics of relief, soils, lithology, ways of usage and occupation, as well as different types of erosion and susceptibility to erosion processes.



PICTURE 2 - Morphopedological Compartments in Arroio Guassupi Water Basin Map – São Pedro do Sul/RS.

Morphopedological Compartment I – MP I

Morphopedological Compartment I is situated in the lower third of the basin, in the northern portion, and it corresponds to 2.13% of the total area, which is 1.68 km^2. It sits in the smaller heights, with altitude varying between 100m and 160m, where declivity varies between 0% and 3%.

The sequence of soils encountered was the Red Alfisol, present in a soft-hilly relief, changing to Melanic Gleysol next to the valley floor. With regard to the geology, there is a predominance of the Botucatu Formation.

In the flood plains, there may be occurrences of slightly more raised surfaces, in which Red Alfisol is found, these surfaces being more susceptible to erosion processes of the ravine type, mainly in the ruptures of declivity. This is due to these soil characteristics, since it has a sandy loam texture in the superficial horizon. Therefore, according to the criteria defined by Salomão (1999), for erosion susceptibility, the relief areas with declivity up to 3% hold very low hydraulic gradient, being classified as non-susceptible to ravines and gullies. In contrast, areas slightly more raised, with medium declivity (3% to 12%) and Alfisol soil have been classified as susceptible to ravines and little susceptible to gullies.

Morphopedological Compartment II – MP II

Morphopedological Compartment II corresponds to 18.5% of the basin, with a 14.6 km^2 area, situated in the NNW portion of the water basin. Its heights vary from 100 to more than 340 metres, and the declivity varies from 0% to 3%, while near the valley floor they can reach 45% on the steep faces of the hills that delimit the basin.

The predominant types of relief are very differentiated. Near the main brook, the alluvial plain can be found, with almost null declivity, varying from 0% to 3%. Toward the heads there are dissected forms, where hills with concave slopes are predominant, and declivity varies from 20% up to more than 45% on the hillsides. The flat-topped residual relief also appears and is formed on the edges of the basin, acting as the aquitard.

It shows Haplic Inceptsoil sequence in the flat-topped residual relief and in the dissection forms with concave slopes, changing to Melanic Gleysol (Gme) next to the valley floor in the alluvial plain. Inceptsoil is associated with the Serra Geral Formation and Gleysol with the Botucatu Formation.

As in the MP I, in this compartment erosion occurrences have not been found. Based on criteria defined by Salomão (1999), the areas where Gleysol occurs have been classified as non-susceptible to ravines and gullies. Areas where Inceptsoil occurs, associated with a more dissected relief, and with concave forms and declivity reaching 45%, have been classified as very susceptible to ravines and little sensitive to gullies. This is due to the predominance of concave forms in contact with the alluvial plain, allowing the concentrated water flow to set off focal points for erosion.

Morphopedological Compartment III – MP III

Morphopedological Compartment III is situated on the left flank of the basin, taking up the southern and south-western portions, with 29.02 km², representing 36.75% of the basin area. Its altitude varies from 100m to more than 340m towards the aquitards and declivity varies from 0% to 3% in the flood plain of Arroio Guassupi, surpassing 45 % on the steep faces of the hills and drainage heads.

In this compartment, a group of hills with concave slopes and high declivity is predominant. Towards the headwalls and by the aquitards of the basin, flat-topped residual relief is seen, with declivity varying from 0% to 6% on the summit, and on its steep faces and hillsides, declivity of 20% to 45% and higher than 45%. The alluvial plain and the valley floor have almost null declivity, varying from 0% to 3%.

With regard to the bedrock, it has been verified that the rocks of the Serra Geral Formation take up nearly all the compartment. The Botucatu Formation rocks appear only along the alluvial plain.

The soil sequence is the following: Litholic Neosol on the flat-topped residual relief, followed by Inceptsoil, Red-Yellow Alfisol, Red Alfisol and Gleysol on the alluvial plain. In some portions, the Red Alfisol are absent from the sequence, which goes from Red-Yellow Alfisol back to Inceptsoil and then to Gleysol.

Differing from the previous compartments, MP III has shown a large number of erosion occurrences, adding up to 32. Because of this great number, which might either be due to the types of relief or the active topography, this compartment is classified as extremely susceptible to ravines and gullies on the Neosol, Inceptsoil, Red Alfisol and Red-

Yellow Alfisol areas, and non-susceptible to ravines and gullies in the Gleysol area in the alluvial plain.

Three different types of erosion occurrences have been identified: ravines, gullies and complex erosions. The ravines occur indistinctly both on the base of the hillsides, in small declivity levels, and on the middle third. Furthermore, they might stretch from the base to the summit of the slopes associated with high declivity levels. The gullies and the complex erosions are associated mainly to the breakage and ruptures of the slopes' declivity.

Morphopedological Compartment IV – MP IV

Morphopedological Compartment IV corresponds to 36.75% of the area, with an area of 33,66 km² and is wholly situated on the right flank of the water basin, stretching from south to north until reaching the MP I edge. This compartment holds the largest representation of the basin and presents a hypsometry that varies from 100m on the alluvial plain to altitudes higher than 340m along the aquitards and drainage heads.

Regarding the relief, the compartment has characteristics similar to MP III. However, the hills show convex slopes, different to the MP III slopes, which are predominantly concave. The declivity on these slopes varies from 12% to 45%. Along the aquitards and the drainage heads, flat-topped residual relief is predominant, with declivity varying between 0% to 6% on the summit and 20% and 45% on its steep faces.

The Serra Geral Formation rocks are seen in the largest part of the compartment, taking up the highest portions, while the Botucatu Formation consists of only the portion along the alluvial plain, downstream.

The soil sequence is the following: Litholic Neosol on the flat-topped residual relief, followed first by Inceptsoil, which takes up the biggest area of this compartment and occurs in the group of hills with convex forms, and then by Melanic Gleysol on the alluvial plain.

In this compartment, 24 erosion occurrences have been identified. This compartment has been classified as very susceptible to ravines and little susceptible to gullies on the Litholic Neosol and Dystrophic Haplic Inceptsoil areas. On the other hand, areas where the declivity is nearly null (0-3%) and there is occurrence of Melanic Gleysol have been classified as non-susceptible to ravines and gullies, although some special attention should be paid to the different forms of land usage.

As in MP III, three different types of erosion occurrences have been identified: ravines, gullies and complex erosions. The ravines occur indistinctly both on the base of the hillsides, in small declivity levels, and in its middle third. Furthermore, they might stretch from the base to the summit of the slopes. The gullies occur mainly on the middle and lower third of the slope, in the ruptures of declivity. The complex erosion is developed mainly on the lower third of the slopes, associated with other mechanisms.

The emergence of the gullies (Pictures 3 and 4), both in the MP III and MP IV, is probably associated with the deepening of the ravines, which might intercept the groundwater and find more favourable developmental conditions. High hydraulic gradients in conditions of developing piping phenomena reinforce the hypothesis that it can evolve from the base up to the summit of the hillside, until it reaches its level base. It is possible to observe the constant presence of a depositional cone on its base, which is basically made of very fine sand. It is also possible to verify some small subsidences on the sandy superficial layer, caused by piping.

The ravines (Picture 5) are not different to the ones found in MP III, concerning genesis and evolution. The declivity and shape of slopes propitiate the concentration of superficial waters that, when combined with deforestation, sets off their development. They develop mainly in the middle third of the slopes. However, some of them stretch from the base to the summit, depending on how it is being used; in a later phase, these may become gullies.

Something very common on hillsides covered by meadows is ravines, originating from small terraces caused by cattle trails. When horizon B is exposed, and because of the sandy loam texture of Alfisol, the incisions might become deeper; it differs to what occurs with Inceptsoil, which has a clay texture that makes the deepening of the incisions more difficult (Picture 6).

The erosions classified as "complex erosions" are situated mainly on the lower third of the slopes above the areas of meadow, with Inceptsoil soil type.

In Picture 7, it is possible to verify that the erosion process begins with subsidence, in addition to the wash, of the superficial layer of the soil. The process occurs on the surface with the displacement of covering sands, and possibly on the subsurface, above the horizon of alteration and horizon B, causing subsidences of the terrain with the formation of ruptures with concave forms and small amphitheatre on the slope. According to Salomão (1994), these amphitheatres, when combined with the emergence of water, have a bigger erosive power, not only for propitiating the concentration of superficial drainage water, but also for developing piping and remnant erosion, very common in drainage heads.

After the process is initiated, other mechanisms start to act together, causing it to evolve. One of these mechanisms is the formation of small ravines inside the erosion, which aid the concentration of rainwater flow, leading to its development. Within some time, some steps are formed; these also evolve laterally, possibly due to landslide and undermining. Luiz (2003) points out that when the erosion processes carve features whose walls expose the horizon B of the soil, a new mechanism of erosion takes place. This mechanism will be associated with the rupture and fall of this horizon aggregate. The author also remarks that from this mechanism, the erosion features tend to increase and expand upstream, following horizon B. In some cases, the development of these erosion occurrences might connect them to ravines, gathering more erosive power (Picture 8).

FINAL REMARKS

The morphopedological approach has proven to be suitable and very useful for this work. Based on this approach, it was possible to map and identify, in the studied area, four compartments, which are relatively homogeneous regarding interactions between bedrock, relief, soils and erosion occurrences. These are called Morphopedological Compartments.

Three different types of erosion occurrences have been identified: ravines, gullies and complex erosions. Compartment III showed the most serious condition, concerning the occurrences of erosion. Thirty-two erosions were verified, totalling up to 50% of the area mapped. The erosions are situated mainly on Alfisol and active relief, this being compartment classified as extremely susceptible to ravines and gullies.

In Compartment IV, 24 occurrences were verified, with special attention to the complex erosions, which, when combined with the ravinement processes, acquire great erosive power, shaping a large area of the slope where they are situated.

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Picture 3 – Small gully over Botucatu sandstone.

Picture 5 – Linear erosion, ravine type.

Picture 7 – Beginning of complex erosion process.

Picture 4 - Small gully over Inceptsoil.

Picture 6 – Horizon B exposed on a small terrace.

Picture 8 – Complex erosion in evolving phase.