Gully erosion stabilization in a highly erodible Kandiustalf soil

Maria Teresa Vilela Nogueira Abdo[A], Sidney Rosa Vieira[B], Antônio Lúcio Mello Martins[C] and Luis Cláudio Patterno Silveira[D]

[A]APTA, PO Box 24, Zip code:15830-000 Pindorama, SP,Brazil, Email mtvilela@apta.sp.gov.br
[B]IAC, PO Box 28, Zip code: 13001-970, Campinas, SP, Brazil, Email sidney@iac.sp.gov.br
[C]APTA, PO Box 24, Zip code:15830-000 Pindorama, SP,Brazil, Email lmartins@apta.sp.gov.br
[D]UFLA, PO Box 3037, Zip Code: 37200-000 Lavras, MG, Brazil, Email lcpsilveira@ufla.br

Abstract
The increase in the area of degraded land threatens the productivity of agroindustry and therefore undermines socio-economical development. The rehabilitation of these areas should be done by a multidisciplinary team. The immediate environmental consequences of the soil degradation are loss in water quality and significant loss of biodiversity in natural flora and fauna. Besides compromising the fertile soil layer there are changes in water flow quality and regime. The absence of conservation practices, the natural forest absence or insufficient plant cover result in the process acceleration. This work shows a stabilization of a degraded soil by an erosive process that produced a gully of approximately 700 meters in length and up to 15 meters deep in some places. Four ponds in a toposequence having lateral spillways channels made of concrete generated a slow passage of the water, stabilizing the erosive process. Altogether conservation practices were incorporated in the parallel contribution areas ensuring the system sustainability over the years (Project of Environmental Recovery of the Experimental Station in Pindorama, SP, Brazil -FAPESP project 95/7818-9).

Key Words
Soil conservation, degraded area recuperation, environmental recuperation, erosion.

Introduction
Erosion and loss of topsoil are the greatest challenges to agriculture sustainability. The biggest cause of soil erosion is water. Loss of nutrient rich topsoil causes decrease in plant growth and soil productivity because sub-soils are generally less fertile. It can be considered that agriculturally valuable soil stock is finite because topsoils are not renewed as fast as they are degraded and eroded. Agriculture will not be sustainable unless the soil be rehabilitated to reverse the degradation process. From the 1980's a new economic development concept arose, incorporating social and environmental preservation, and a new ideal emerged: the sustainability, defined as a set of practices that involve the appropriate management of resources to satisfy human needs, whilst maintaining or enhancing the environment quality and conserving the natural resources. In Brazil, although there are no exact data, deforestation followed by agricultural activities are major degradation factors. There is beneficial natural erosion which forms soil through parent material decomposition process through the action of temperature, winds and rains. On the other hand, accelerated erosion is a result of human misuse of land where soil losses are no longer compensated by the geologic substrate or by the alluvial contributions. The water infiltration impossibility generating runoff and so promoting the material drag and deposition of material from various soil horizons, is the erosion fundament. Moreover it should be noticed that 95% of soil erosion is due to the poor water infiltration and accelerated runoff and only 5% due to the land slope. Whatever the agent, erosion occurs in three stages: breakdown, transport and soil material deposition.

Some authors divide the water erosion into laminar (superficial) and linear, presenting 3 types: grooves, ravines, and gullies including underground e.g. tunnel gullying. Gullying accounts for much erosion and is hard to control. Gullies can be branched, deep, presenting irregular walls, and presenting "U" transverse profiles. This form of erosion is more complex and more destructive, as is the product of the combined action of superficial and underground runoff leading to a morpho-hydro-pedologic imbalance due to inappropriate use and occupation of the land. In this study we report on the soil erosion problems of the Pindorama municipality (Vieira *et al.* 1997 and Abdo, 1997). These soils, mostly classified as Kandiustalf, have high erosion susceptibility (Lepsch and Valadares 1976).

The São Domingos river basin, where Pólo Apta Centro Norte is located, erosion susceptibility is mostly in the Classes I and II (very high and high). There is 50 years of accumulated data on erosion at Polo Apta Centro Norte, and some soil conservation practices developed in the county to reduce the problem are described by Vieira *et al.* (1997). According to the author, the study area involves a gully 700 meters wide and in some places up to 15 meters deep. The gully has arisen as a result of improper slope management of Kandiustalf soils, which are highly susceptible to erosion. The place chosen was a strategic location to preserve the forest nearby that had an importance for local biodiversity. As an action plan, four ponds were built to reduce the velocity of surface runoff. Each pond had concrete overflows channels to prevent channel erosion, this way stabilizing the installed erosive process. Soil conservation practices were introduced throughout the catchment. Also the agricultural experimentation area located above the gully got a special attention with continuous vegetal covering was maintained to avoid the erosion. Animals were removed from the region neighboring the water in order to maintain soil cover.

Material and methods

Area description and characterization

The erosive process happened in a severely gully-eroded landscape with a Kandiustalf soil, primarily clay eutrophic sandy, which are well drained and have an average slope from 2 to 10%. This slope and a sandy A horizon and a textural gradient to the B horizon make these soils very susceptible to water erosion (Lepsh and Valadares 1976). This susceptibility to erosion was aggravated by inadequate management of the area, which for decades had been used as pasture with no soil conservation practices. The coffee crop planted down hill, without enough conservation measures and with a very low production was soon transformed into pasture in this area that was already degraded. Excess runoff increased deeply the cattle tracks towards the water bed, in the lower part of the area. As a result an erosion of considerable proportions was formed as it can be seen in Figure 1.

Figure 1. General gully view before the work.
Soil and sediment flowing down the eroded gully has plugged the lower drainage channel.

Soil management and prepare

In order to control the rate of water flow through the gully, four ponds (gully dams) were constructed aligned perpendicularly to the erosion direction. In addition, the distance between dam walls was calculated to allow water to back up almost reaching the end of the previous dam (except the first one). This way would be possible that the water from a pond pour into the next pond, and so forth. This way the water could be conducted from the beginning to the end of the erosion without carrying soil. The positions of the ponds were marked out and the vegetation present on those positions were removed so that the central part of the ponds where the soil had to be the base of the dams could be strongly compacted, generating a strong intern wall, such that the water could not pass through inside or down the pond. Within this marked central area, from four to six meters wide, a technique called "cut off" was used. This consisted of removing soil material, until a firm soil was reached, preferentially a clayier soil than the original one. Once the central part of each dam was completed, soil to fill the “cut off” was brought from a different area, from a B horizon (so, clay soil), placed in 20-30cm lays and then compacted manually or using a pressure equipment pulled by a tractor. When a layer was fully compressed, new layer was poured, and so on until the desired height was reached according to the calculations. Water was applied to raise the B horizon material to a moisture content suitable for maximum compaction with a compressing process. Figure 2 shows a pond finished.


Figure 2. Pond construction.

After the construction, the ponds sides were covered with grass. The whole area that was cleaned initially was covered with grass to avoid erosion around the ponds, which could compromise the investments done as well all the work done (Figure 3). To enable the free running of the flow of excess water from rain, concrete drain canals were constructed to minimize dam wall erosion in storm conditions.


Figure 3. Grass planting in the dams.


Figure 4. Present view of the dams.

Results and discussion

The gully erosion has been stabilized in the highly erosive Kandiustalf soil by avoiding channel flow and controlling the velocity of surface run-off. Actually, as it has been ten years from the beginning of the project, it can be considered that the stabilization/rehabilitation process offers farmers a solution to the erosion problem, minimizing their loss of soil and returning the land to a productive state (Figure 4). In the example presented, the gully which was formed by previous unsustainable agriculture practices was stabilized avoiding pollution and forest destruction that is just above the eroded area, ensuring the area stability. The area that was previously used for agriculture was unviable to any activity due the progressing erosion and it is now suitable use again without erosion risk.

Conclusions

Within this context it is still worth considering the idea that it is always better to prevent than solve a soil erosion problem already installed because once the soil loses its physical and chemical characteristics it will hardly get them back. It is also important to emphasize that when the erosion problem is detected, the actions taken to reverse the process must be based on a multidisciplinary approach which considers all factors at work in the erosion feature, its surroundings and necessary restorative structures and vegetation. In the context of this study to solve gully erosion, the "drainage divide concept" was able to minimize the local soil losses and to ensure that the work was done for sustainability, restoring a sustainable vegetative cover.

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