# EXPERIENCES IN THE STABILIZATION OF A LARGE GULLY AT SPRINGS AREA PROPERTY FROM AGUA MINALBA VENEZUELA.

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**Abstract:** This paper presents the experiences accumulated in the stabilization of a large gully located on the border of the road leading to Macarao National Park in Miranda State, Venezuela, by the application of The Vetiver System (VS). The different phases of analysis, design, installation of underground drainage, the vetiver planting method and maintenance (Chrysopogon zizanioides), and the results obtained are described.

The gully was caused due to the expansion of an external road by a public institution. At that time a major portion of water drainage of the road were taken into the land of Agua Minalba. Redirected water volumes, soil constitution, and the heavy rains began the erosion processes in 3-year record of the incident reaching a difference from 5.80 meters to 10.20 meters in height at the site developing a large gully. During the execution of the work also a slope located in front of the gully was modified where terraces were constructed but were not stabilized. These slopes have also become a source of sediments.

The works carried out between August and September 2009 to stabilize the gully were to partially block the entry of water into the gully, install a temporary underground drainage system consisting of three tanquillas and a battery of interconnected hoses. Topography of slopes was reshaped, and then, vetiver was planted using rappel techniques.

The adaptation of Vetiver went through difficult times due to a strong dry period caused by the "El Niño" phenomenon. This required the application of complementary irrigation aided by foliar fertilization. After the rainy season 2010 started dense barriers were formed, free access was given to water and drainage and Vetiver System (VS) worked fine until mid May 2011. Later, because of mismanagement, the entire system located in the bed partially failed, although the vetiver in the slopes remain unchanged. Currently, it is being evaluated to develop recovery efforts, replanting damaged areas and modifying the drainage system.

## 1.-INTRODUCTION

### 1.1 Location and problems:

In the mountain range region of the central coast of Venezuela, near Macarao National Park, Guaicaipuro Municipality of Miranda State, Venezuela, it is located an area where natural springs emerge. In the national park area are emerging aquifers that supply water to a region near Caracas. In that area it is also located the property where is based "AGUA Minalba" who owns a significant portion of the land planted with Vetiver on contour. (Photo 1).

On the occasion of executing the work of extending a road to the park and through the property, the topography was modified and water works were built consisting of a perimeter ditch located at the foot of the slope, with a series of tanquillas leading water collected under the road via a concrete pipe of 0.60 m in diameter

One of the tubes is located on the site where the gully was subsequently developed (N: 10 º 22 '33 "O: 067 º 05' 50" at 1450 m). (Photos 2, 3 and 4)

Photo 1: Vetiver on the site of AGUA MINALBA

Photo 2: Gully in the beginning (2.006)

Photos 3 y 4 State of the gully in May 2009, befote applying VS

The soils of the area where the gully is located are sandy loam, containing 65% sand, 29% silt and 6% clay. The soil erodibility caused the gully to progress from 6.00 meters to 10.2 meters (pictures 5 and 6).

The chemical composition of soil is: pH 5.5, nitrogen: 0.02% Phosphorus: 7 ppm, Potassium: 45 ppm.

The rainfall season in Venezuela is between May and October, although recently there has been a remarkable change of that cycle, particularly in the last 3 years due to the El Niño and La Niña phenomena.

 

Photos 5 and 6: The depth reached by the gully. The size of the people serves as a reference (Aug. 2009)

Erosion caused a difference in height of 4.2 meters in just 3 years of monitoring, as shown in the curves of Figure 1, while on the slopes outlined irregular shapes that became in some cases vertical. Some areas showed fractured soil blocks.

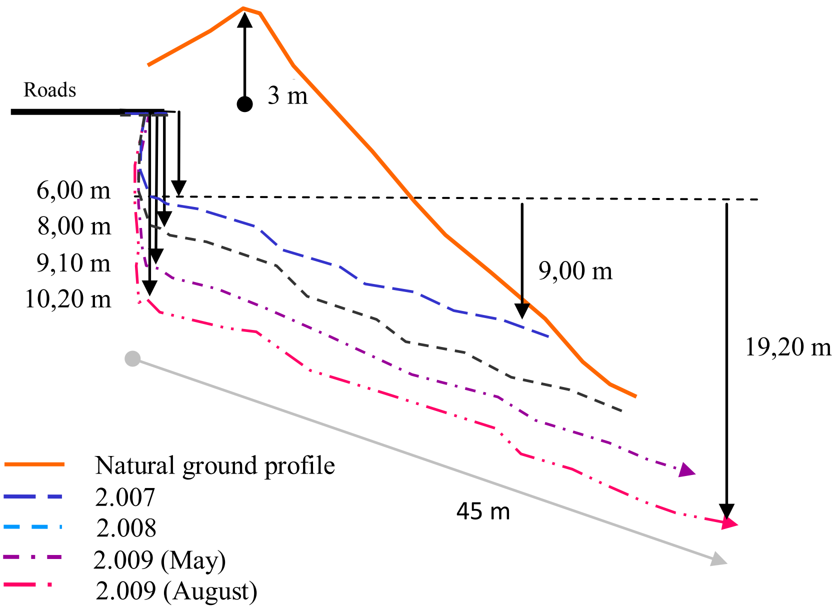


Figure 1: Curves of annual erosion

## 2. THE PROJECT

### 2.1 Drainage

Several options of classic engineering were taking into account, between them, to cover the slopes with armed concrete and to construct a channel in the bed of the gully, but it was discarded due to the high costs involved. The results obtained by the client with vetiver in other areas orientated to approach the problem with the technology associated with Vetiver System (SV). Several projects were evaluated, finally deciding to lead temporarily the waters across an underground drainage and to consolidate with Vetiver the whole affected zone.

We designed a system of collecting tanquillas with two chambers where the first performs a dual function: on the one hand to capture the water falling from above, and on the other, cause a hydraulic jump to attenuate the energy. The second chamber delivers water to a battery of 16 hoses HDPE 4 "each one to reach the final place of discharge. The role of intermediate tanquillas is to reduce water velocity caused by the gap between them.

The original project included a baffle placed over the slab from the upper channel where a battery of steel chains 1 / 2 "will dissipate waterfall forces. This phase was never concluded because an earthquake occurred during the construction phase and the channel and slab collapsed. The new scenario led to the construction of a channel of corrugated galvanized pipes delivering water into the receiving tanquilla.

A blockade of the external tanquilla, was also considered, to avoid water to enter into the microbasin while underground drainage system was constructed Later, it will be open to allow water flow through it. In this way, the surface area only drains water coming directly into the gully, or surplus that may occur when heavy rains exceed the capacity of the internal drainage system. The design was conceived for temporary use while VS was consolidated in the bed.

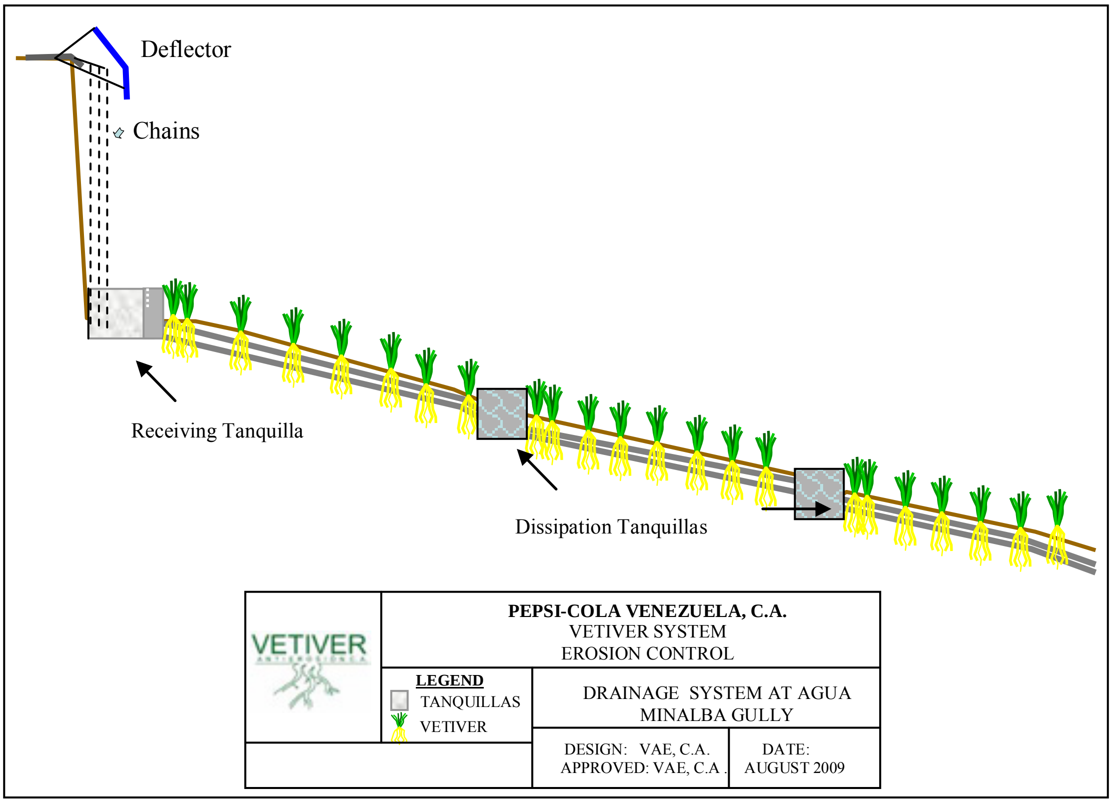


Figure 2: Original design

**3 .- THE VETIVER SYSTEM (VS)** DESIGN:

Vetiver (Chrysopogon zizanioides) has some characteristics that make it ideal for use in bioengineering as it develops a massive and deep root system, with a tensile strength of 75 Mpa, equivalent to 765 Kg/cm2 (Hengchaovanich, D et al, 1988), and displays an upright and stiff foliage, capable of retaining water flows (Metcalfe, O et al.) The plant also tolerates adverse conditions including high soil pH range and the presence of heavy metals (Troung, P, 1999). In view of these properties and the problems under study, we chose to use technology derived from research and applications of this plant, known today as Vetiver System (VS) technology.

In response to the situation, suffice it to say: soil type, slope angle and rainfall in the area, it eas decided to apply a Vertical Interval between barriers of 65 cm (IV = 0.65 m). Similarly, considering the inclination of the slopes and difficulties in trenching due to the risk of soil falling into blocks, we chose to use plastic bundles and plant on them.

For the bed of the gully we chose a fishbone design with the vertex down (Rodríguez, O, 2003) leading the major volumes of water into the center well away from the walls of the slopes, while the sides of the barriers were placed parallel to the tanquillas with the object to anchor them.

## 4 .- BUILDING SYSTEM:

### 4.1: Tanquillas and Hoses:

Three tanquillas were built settled on solid ground. The first one (receiver) is made of reinforced concrete and the other two (dissipation) are soil-cement, with concrete floor.

The receiving tanquillas has a grid to prevent objects larger than the diameter of the hoses to pass into and obstruct them. (Photos 7 and 8).

Photo 7 Receiving Tanquilla

Photo 8 Detail Grid

The tanquillas are connected to a battery of 16 4-inch HDPE pipes; they lead the water to the disposal site (Photos 9 and 10).

Photo 9 Piping system

Photo 10 Transition Tanquilla and hoses

**4.2.-Reprofiling:**

Once the previous phase of work conclude, it was started the reshaping of all sides of the slopes of the gully in order to eliminate the sections of soil surface that had fractures and / or irregularities in its geometry. To this end, workers tied with a nylon rope harness and anchor them to points well assured (Photos 11 and 12). Then, with appropriate tools began to work by sections from the upper east side, until they reach the lower part. Continued through the front (north side) and then applied the same methodology to the west side.

Staff hired for these tasks are members of the environmental group and rescue "Condor", all residents in the town of San Pedro de los Altos, near the site of the gully.

Photo 11 Start the reprofiling

Photo 12 Securing the fall of a worker

After completing the reprofiling work, the excess of soil material that was in the bed of the gully was removed. To accomplish this, a method that consists of projecting a jet of water under high pressure was used, which remove large masses of earth, while the one settled in bed was compacted.

**4.3 .- Planting:**

The work was executed planting horizontals strips starting from the top of the walls (Photo 13). In the first instance, it is made a little dig at each planting point (Luque et al, 2006), there was placed a portion of diammonium phosphate, it is covered lightly and then placed a substrate consisting of a mixture of wood chips and horse manure, which was selected because the chip size did not allow their passage through the mesh grids. 9 plants / m were planted (Photo 14).

Photo 13 Planting in horizontal stripes

Photo 14: Retained by the mesh substrate

Planting at the bottom (bed) of the gully was trenching rather than individual planting points. The process of fertilization, manure application and planting was the same as described above. In all cases, each day ended with the irrigation of plants.

**5 .- MAINTENANCE:**

The planting works were completed by mid-October 2009, when it was supposed to still remain scattered showers. However, as a consequence of the climatic phenomenon "El Niño" they went away submitting the region in particular and the country in general, to the most severe summer of the last 50 years.

Then, forecasts were taken for irrigation through the use of tankers, but the scarcity of water in the area restricted its use for such purposes. This situation led to apply only 3,000 liters per week spread over 2 watering each week for four (4) months, which caused a plant mortality of 12%. The highest mortality was found in the slope walls.

In the month of May 2010, after found that the rains would continue its usual cycle we proceeded to kill weeds, to replace the dead plants, apply granular fertilizer (N2 + micronutrients) and replace all dead plant material. Equally there was done a selective pruning and the fertilization of the vetiver.

**6 .- RESULTS AND DISCUSSION:**

It has been frequently monitored the behavior of the gully and vetiver development during the period that goes from October 2009 to May 2011 and upon observations the following comments are done:

**6.1 .- Gully:**

Rains during 2010 season were abundant, in fact, the beginning preceded one month the historical cycle, and they caused mudslides in areas close to where the gully is located. However, it was not observed the reactivation of erosion in areas previously treated with vetiver, except in small areas on the walls of the slopes where it had not been a good development for the time (photos 15 and 16).

Foto 15: Failure observed in fatigues

Foto 16: Material retained by the barrier shot lower

The slopes of the gully are quite stable, although the initial development of vetiver was slow on the walls and the plants are smaller as compared with the plants in the bed.

**6.2 .- Drains:**

The drainage system worked well from July 2010 (when it was given full access to the water) and May 2011. During this period heavy rains occurred in the months of November and December (2010) and the beginning of May 2011 which caused damage to surrounding areas, but the system worked well. Notably, during the construction phase of the road drainage channel, made by another company, all the sediments from the excavation were overturned in the receiver tanquilla and some barriers of vetiver, without later remotion (Photo 17). Moreover, the slope on the front (photo 18) significantly increased the sediment supply to the gully. From the second week of May 2011 the system collapsed.

Foto 17: Sand deposited in the recipient tanquilla. vetiver barriers are seen covered (October 2010)

Foto 18: Slope that provides the gully sediment Arrow: direction of flow. Circle: Capture Tanquilla

**6.3 .- Vetiver:**

• Vetiver growth was inharmonious because of water stress to which it was subjected at the initial stage for a significant period.

• This resulted in the death of a significant number of plants, particularly in the walls of the steeper slopes.

• Similarly, vetiver plants with lower development were located on the slopes.

• The largest plant growth occurred in the bed of the gully.

• Plants respond well to the work of fertilization during drought

• In July 2010 it was noticed an infestation of pastures defoliant worm (*Mocis latipes*) throughout the region, which also attacked vetiver (photos 19 and 20). Control involves critical applications of DECIS (deltamethrin), a pyrethroid type insecticide at the rate of 1cc/litro with good results.

Photo 19: Worm grass peeler

Photo 20: Damage caused by the worm

• After controlling the worm it was found that the attack caused no significant damage in the crop, except in some young plants.

• Between October 2010 and early May 2011, the VS work without erosion evidences in the gully, on the contrary, trapped sediment was found behind the barriers. Vetiver handled well, both the water flows in the microbasin, as well as that entered through the external drainage system. During that time, sediments were observed trapped in bed (photos 21, 22).

 

Photos 21 and 22 sediment trapped by the barriers placed in the bed of the gully (May 2010)

All the gully was stabilized in less than 1 year, despite disturbing elements of the system were observed during monitoring. In view of this, recommendations were made to remove excess sediment and eliminate weeds present (photo 23).

Photo 23. State of the gully in October 2010.

• This activity was conducted by a different company than Vetiver Antierosion, CA, in early May 2011, improperly handling vetiver pruning to 25 cm from the floor, cutting off the foliage and with it the ability to retain water flows and slow runoff (photos 24 and 25).

Photo 24: Vetiver pruned to 25 cm

Photo 25: Waste dumps on vetiver weed

As a result of excess sediment that smothered a portion of the bed barriers, and because of the bad practice done by pruning in the second week of May 2011, the water moved freely through the bed of the gully dragging a major portion of the soil surface and restoring soil erosion processes already under control by the vetiver, however, the walls of the banks did not collapse (photos 26 and 27)


Photo 26: The gully bed collapsed


Photo: 27 barriers were not damaged slopes

• An important fact to note is that the abundant presence of vetiver roots in the gully did not allow the collapse of the bed It was observed some of them anchored within schists, which supports research by Hengchaovanich, on the ability to penetrate rock (photos 28 and 29)


Foto 30 Abundance of roots


Foto 31 Roots anchored in shale

**7 .- CONCLUSIONS:**

Given these results to date, we can assume that vetiver can be used to address major gullies. Through this experience we conclude that:

• It is confirmed the ability of vetiver to adapt to any soil condition and anchor on the rocks.

• Although it was subjected to water stress to a high percentage, vetiver survived in a dormant state until the arrival of the rains.

• Foliar feeding with nutrients and amino acids help the plants to withstand long summers.

• The ongoing erosion processes were stopped after the planting of vetiver.

• The use of vetiver on slopes steeper than 45 ° is feasible, but requires technical and specialized staff for planting.

• Costs associated with this type of project is significantly less than treatment with other solutions, "hard" engineering.

• The monitoring allowed early detection of situations that could have produced adverse results before the establishment of vetiver.

• Peeler grass worm does not harm significantly adult vetiver plants.

• The high sediment load and particularly the height of pruning of the plants affected the failure of the bed.

• The vetiver planted on the slopes of the gully is strongly rooted.

## 8 .- RECOMMENDATIONS:

### 8.1 .- Hoses:

Given the experience of the difficulties taken for installation of the hoses and the collapse of these system we recommend:

- Repair the drainage system.
- Use rigid pipe with a high roughness index, the more effective diameter and length not exceeding 6 meters.
- Replace the 16 lines HDPE Hose 4 "by 2 rigid pipe 16."
- Set the final drainage system, with both dissipation tanquillas built in reinforced concrete.

### 8.2 .- Vetiver:

- We must have trained staff for this type of work. You must be strict with the security provisions to the staff and the environment.
- If you work during the rainy season, you should check the entry of water into the gully before the planting of vetiver on the bed, channeling higher volumes to another watershed, or drive it via groundwater.
- If the work is done in summer, it is necessary to irrigate every day during the first month.
- The following waterings may be inter day from the second month, and weekly after the third month.
- Apply fertilizer and weed control to promote rapid growth of vetiver for the first 6 months.
- Contour lines must be well designed. If in the course of the outline there are rocks, small rocks should be removed, while Vetiver must be planted at the bottom of larger rocks to anchor them.
- Make the apex of the fishbone less acute. The distance between lines should be located at 1 meter
- Perform periodic monitoring to evaluate the development of Vetiver and promptly address any erosion event if detected within the gully.
- Maintenance should be limited to control weeds before they bloom, and the fertilization of vetiver
- Maintenance work must be performed by qualified personnel.

### 8.3 .- Slope outside the gully:

In order to prevent the migration of large volumes of sediment to the gully microbasin that could suffocate vetiver in the bed, and in order to overcome the erosion which can lead to landslides on the slope, it is necessary to stabilize it. Given the results, apply the VS, which we believe should be associated with forage peanut (Arachis pintoi).

## 9 .- REFERENCES

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## 10 .- THE AUTHOR

Rafael Luque Mirabal worked for 30 years in inspection of civil and electromechanical works. During the past 12 years has specialized in Vetiver Bioengineering, through various studies on the subject, and as the manager in the direction and supervision of bioengineering works, including the environmental recovery of bauxite mine in Los Pijiguaos, likewise, in the protection of infrastructure such as roads, buildings, urban planning, transmission towers, etc..
He has an accreditation on Vetiver Bioengineering Technical Excellence (class 3) given by the TVNI during the ICV-4 (2006). He is a lecturer nationally and internationally on the field. He is President of Vetiver Antierosion, C.A.