Slope Stabilization in Itaipava-Petropolis, RJ, Brazil Using Vetiver Solution - A Total Success.

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Land slide events of catastrophic proportions recently occurred in January 2011 due to intense rainfall - a usual occurrence in January and February in the region south Brazil.

Over 770 deaths have been reported, plus over 400 missing people in the cities of Petropolis, Teresopolis, Nova Friburgo and other small places, all located on the hill slopes of the State of Rio de Janeiro.

On February 02, 2008 heavy rains occurred bringing with it material damage and injury to the owner of the ranch located in Itaipava, district of Petropolis. In 2011 the same area has again been affected by rains with a difference in that the death toll and damage is higher.

In 2008 many of landslides occurred in the area and one of large magnitude reached the house owned by Mr.Eboli - he had suffered an injury and house was damaged.

Before the landslide, the hill was covered with natural grass and native bushes. The landslide has the shape of a concave basin of 1840 m^2, with a length of 74 meters and a width of 43 meters, funnel shaped towards the lower side.

Elevations: highest point is 817 meters and lowest point is 770 meters.

The inclination of the slope is steep - on upper half 97% or 44 degrees, approximately 1:1 (H:V) and the half lower part is 64% or 33 degrees, approximately 1.6:1 (H:V). One can see that the inclination is steep, and prone to landslides. See figures (1) and (2) below

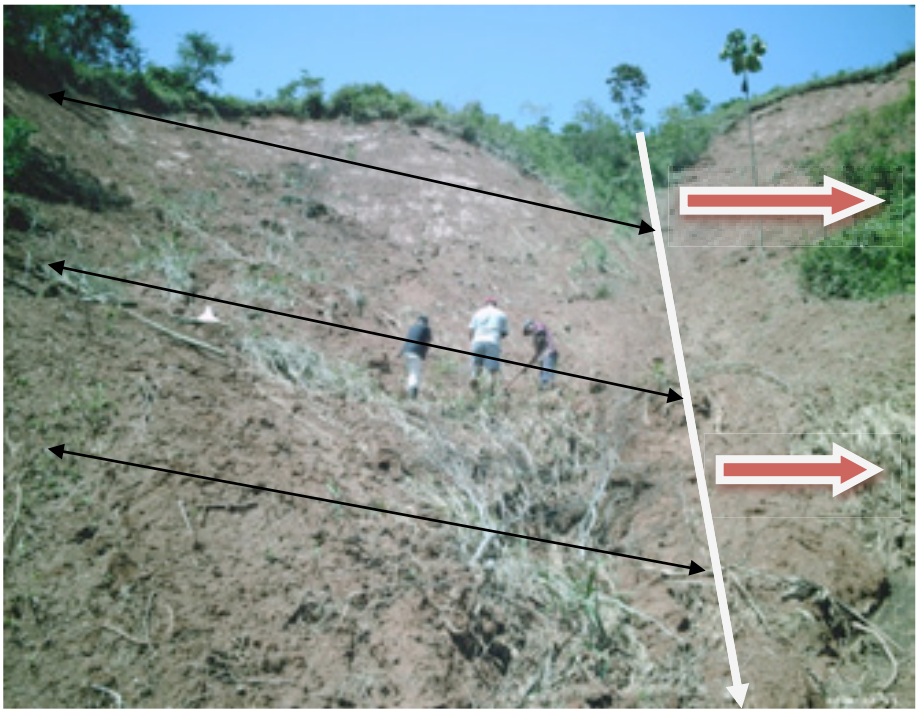

FIG. 1. **The upper part of the landslide in Eboli ranch**

The landslide in neighbor's land

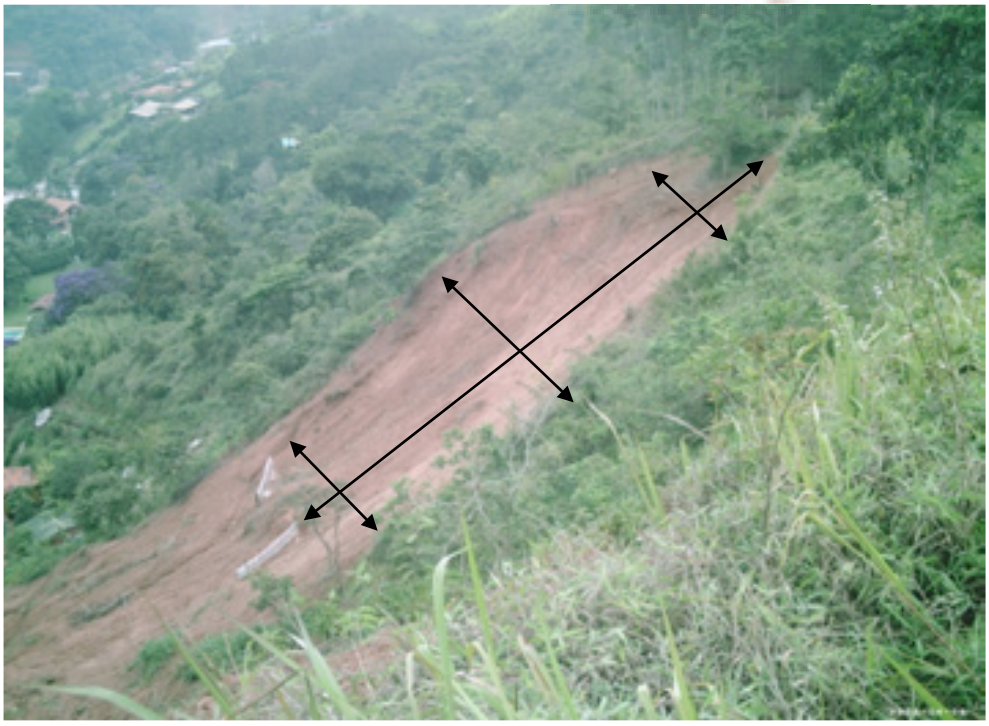

FIG. 2. **The area where was planted about 8500 slips**

Right after the landslide on 02/02/2008 the owner of the ranch, Mr. Eboli, retired Telecommunication Engineer learned about a plant, *Vetiveria zizanioides* (Vetiver grass) available in Brazil and appropriate for use in slope stabilization. He studied the plant characteristics and decided immediately to try and use it on his landslide area with the purpose of long term slope stability. Besides Eboli, four more people have been working in the task of recovering the slope.

Full photographic details of the work by João Henrique.Eboli.can be found at: https://docs.google.com/leaf?id=0B3E8MMCy36wZYmJkNDNmZDYtZWM2Ni00ZmQxLWE3OWYtZTE5NjdhNDYyZjM1&sort=name&layout=list&pid=0B3E8MMCy36wZOGU3M2EzNjEtYzU0OS00ODU0LTkxODctYjA2NGI0ODc3ZTgy&cindex=1.

The slipped slope was stabilized by making a channel to deviate the surface water acting from the head and laterals of the eroded basin; the soil was prepared manually, after which contour lines were plotted and vetiver hedgerows were installed, using about 8500 vetiver planting slips in order to prevent surface erosion and promote inside the basin a truly "live nail" pinning the soil to the subsurface "C" horizon. In addition around the boundaries of the slide area the plants were placed as 2/square meter.

The soil between the Vetiver hedgerows was totally covered with mulch (straw and sawdust — 0,5kg/m2) and jute bags meant to improve the soil roughness between the leveled lines.

The Vetiver slip was planted at 10 cm (4 inches) center to center and the lines varied between 1.0 and 1.5 meters.

The Vetiver was planted in July/2008, completed by December/2008.

In the year 2009 and 2010, 2300 additional slips of Vetiver were planted. The surface drainage was also completed in September 2009 and a rain gage (fig.3) was made available in the area studied

FIG. 3. Home made rain gage type.

On the lower part of the slope, in addition to the Vetiver planted as a “live nail”, some leguminous plants, shrubs, fruit trees, grass, were planted and today 95% of the area is fully covered with vegetation.

Before entering the public drainage line the runoff water was collected and run over 9 sediment boxes, to separate water from silt material.

After three years since the landslide, although suffering strong winds and heavy rains, the hill slope is fully intact with the help of the Vetiver that is now fully developed and firmly holding the soil.

See the figures (4) and (5). The photos were made after the recent 2011 rainfall events

This effective slope stabilization and the much reduced sediment runoff provides a real life testimony for Vetiver which thus far remains in great condition

The ultimate test was on the 11 and 12 January 2011, when after an initial 18 mm it rained 95 mm over a two and half hour period. Altogether a precipitation of 113 mm in less than 24 hours was measured by rain gage placed at the house.

It should be noted that in December 2010 the monthly precipitation has reached 350 mm and during the week before 11 January 2011 the precipitation was 60 mm.

The soil on the hill has remained stable and the water discharged into the public drainage line is clean, with no dirt in it.

The maintenance is done by removing dry leaves of Vetiver (allowing more shoots to flourish), control of ants, cleaning of the boxes and drainage ditches, pruning the Vetiver grass and keep an eye on the integrity of the slope. Any observed failure will be immediately rectified.

Partial view of lower portion of the slope. Fig. (6)

So far the slope has maintained its integrity demonstrating and proving in the real world that the plant *Vetiveria Zizanioides* can rehabilitate and maintain slopes effected by land slides.

This is due to properties of having strong and lengthy roots, equivalent to an engineer's soil nail.

The cost of the *Vetiveria Zizanioides* solution was no more than US 29,000 dollars in such area protected having 1840 square meters. About US$ 16 per square meter or US $ 1.6/square feet. The cost included all expenses with materials and workmanship, including insurance, meal, extra hours.

The cost of US$ 1.6/square feet is really affordable, even to Brazilians with low income.

Perhaps this is the true defect of Vetiver Solution: - **Too cheap to be true**. **Too cheap to believe** when compared to heavy stone structures.

The Vetiver will fail where misapplied or not properly maintained. The Vetiver when installed and managed following the correct technical guidelines is a guaranteed success.

The Vetiver Solution can be complimentary to other slope stabilization methods. Take for instance the stone wall, widely known, as Gabion Wall. This technology can be greatly enhanced by planting Vetiver at the toe of the gabion wall, it will assure firmer roots into the foundation soil where the wall is based. Also Vetiver can be placed in the voids of the wall if placing Vetiver, more "natural soil nail" will hold the wall into the soil mass, exerting great adherence. There are instances where the Vetiver Solution can be used as a stand alone technology or can be combined with others. Each case must be separately evaluated and defined during project design.

Conclusion:

The use of *Vetiveria Zizanioides* for slope stabilization of slopes no steeper than 1: 1 (H:V) if done with appropriate care, using adult slips and distributed fairly well in both direction, horizontal and vertical, can assure stability of the slope, even after the slope suffered a slide on it.

The basic design is to create an effect of natural soil nailing, in such a grid that the roots of vetiver act as a true set of "nails" holding the soil mass, preventing incremental erosion, and reducing the chances of pockets of water on the slope that may result in high hydraulic pressures leading to slippage. The roots of *Vetiveria Zizanioides* can develop up to 3 to 4 meters deep into the soil mass, and has the strength of about 1/6 of mild steel bar (75 MPa).

What else we need? This is Cheap and Safe Solution.

Lets make use of it.