Vetiver Solution – A Total Success in Landslide Stabilization at Itaipava, Petropolis, Rio de Janeiro, Brazil

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ABSTRACT

Early in February 2008 heavy rains and intense thunderstorms occurred for one week, causing several landslides and property damages in Rio de Janeiro Brazil, which attracted world wide attention.

Before the landslide a hill at Itaipava, Petropolis district, was covered with natural grass and native bushes. A very large landslide occurred following prolonged rain, it had the shape of a concave basin, with a length of 74m and a width of 43m, funnel shaped towards the lower side, total area of 1840 m^2 and vertical height of 47m.

The gradient of the slope is very steep: 97% or 44 degrees on upper half, and 64% or 33 degrees the half lower part. The soil is a mixture of clay, silt and sand.

The first step in rehabilitation was to stabilised the slipped slope by installing drainage chanels to divert the surface water coming from above and sides of the collapsed basin. Vetiver slips were planted at 10 plants/m and Vetical Interval between 1.0 and 1.5m. The total plant number used for both sections, including replanting for maintenance was 8 600 plants for the upper section and 2 750 for the lower section

The total cost of the Vetiver solution was no more than US$ 16 per square meter This cost is really affordable, even to Brazilians with low income.

Results todate clearly show that:

- The use of VS for the stabilization of slopes not steeper than 1:1 when implemented appropriately, using mature slips and planted properly can assure stability of the slope, even after landslide occurred on the slope.
- Vetiver System Technology is a low cost, effective and safe solution for the rehabilitation of landslides and reduction of landslips incidence in high rainfall region
- This work clearly demonstrated the real potential of the VST in mitigating the effects of the climate changes that currently provokes the natural disasters on the environment, as it happened here.
- Perhaps the only real defect of the Vetiver solution is: ***Too cheap to be true, too cheap to believe when compared to heavy stone structures*.**

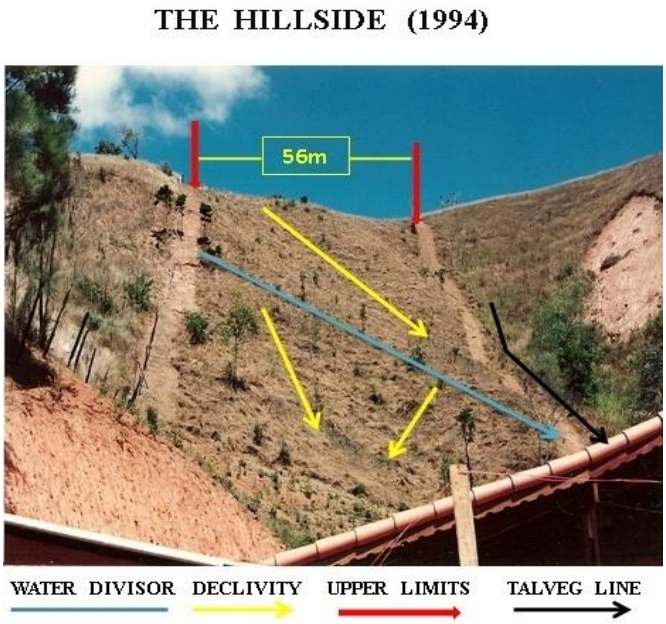
Keywords: Landslide; Steep slope stabilization; Sediment control; Water spreader

INTRODUCTION

On February 2, 2008 heavy rains and intense thunderstorms occurred for about 3.5 hours, bringing with it material damage and injury to the first author and owner of the house located in Itaipava, district of Petrópolis. Before the accident occurred, heavy rains continuing for one week.

Before the landslide, the hill was covered with natural grass and native bushes (Fig.1). The landslide had the shape of a concave basin of 1840 m^2, with a length of 74m and a width of 43m, funnel shaped towards the lower side, and vertical height of 47m (elevation of the highest point:817m and lowest point: 770m).

Fig. 1: Before the landslide the hill was covered with natural grass and native bushes



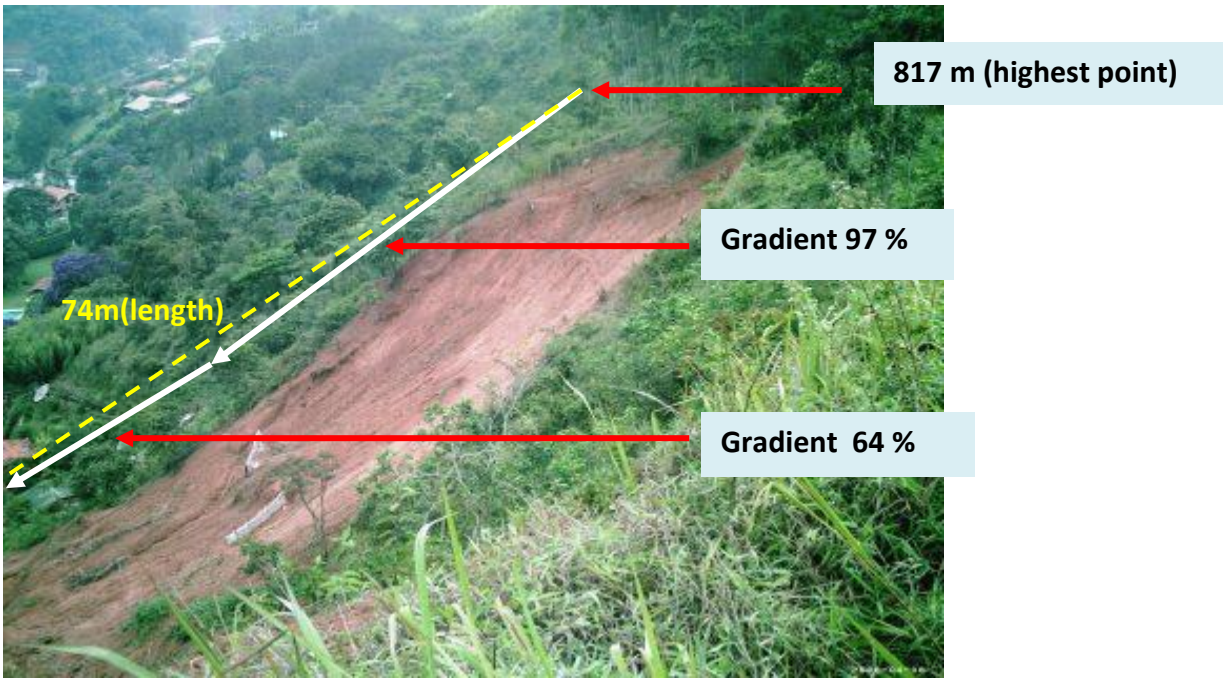
SLOPE CHARACTERISTICS

The gradient of the slope is very steep – on upper half 97% or 44 degrees, aproximately 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 landslide (Fig.2).

SOIL CHARACTERISTICS

- **Texture:** Clay: 18,6%; Silt: 44,5%; Sand: 60,0% (average for all the slope after the landslide)
- **Chemical compositions:**
  - ***Upper part of the slope****:* pH (water); 4,9; Ca + Mg: 1,0 cmol/L; P: 1,2 mg/L; K: 20 mg/L; Al: 1,1 cmol/l
  - ***Lower part of the slope*** : pH (water): 5,5; Ca + Mg: 1,0 cmol/L; P:1,2 mg/L; K: 22 mg/L; Al: 0,7 cmol/L.

Fig. 2: Very steep gradient, 97% on upper half and 64% on lower half



IMPLEMENTATION

Right after the landslide on February 2, 2008, the first author, a retired Telecommunication Engineer, read about a plant, ***Vetiveria zizanioides*** (Vetiver grass) (Ref.1, 2), available in Brazil and appropriate for use in slope stabilization. He studied the plant characteristics (3) and decided immediately to try and use it on his landslide area with the aim to provide long term slope stability. The first author planned, designed and implemented the stabisation and rehabilitation of the slope with four employees.

The first step was toprotect and stabilise the slipped slope by installing drainage chanels to divert the surface water coming from above and sides of the collapsed basin (Fig.3).

The land was prepared manually, then contour lines were plotted and vetiver hedgerows were planted, using about 8.600 vetiver planting slips to prevent surface erosion and providing the basin with truly "live nail" pinning the soil to the subsurface "C" horizon. In addition, the planting at about 2plants /square meter was done around the boundaries of the landslip area.

Site Preparation

Before the full developement of vetiver hedges, silt fences were used to control sediment at various points of the slope as an aid to control rainfall run off. These seals were handmade with inert material such as straw, coir, jute, or sawdust, wrapped in a cotton blanket (old coffee bags). Over time, this material is broken down or wrapped in grasses.

Planting Material Preparation

Vetiver slips were raised in nursery first when young and when vigorously growing roots emerged the slips were ready for planting out (Fig.4).

Fig 3. Whole site with bordering drainage chanels

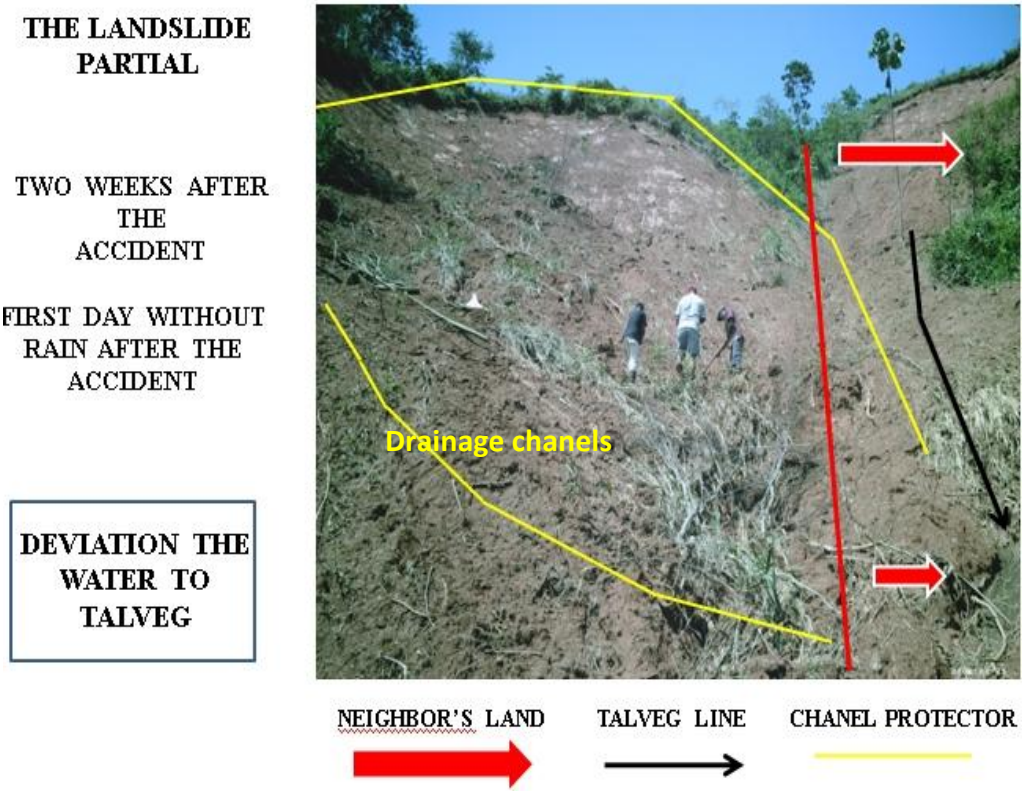


Fig 4. Vetiver nursery and healthy vetiver slips ready for planting out

Plant Establishment

The Vetiver slips were planted at 10 plants/m (4 inches) and Vetical Interval (VI) varied between 1.0 and 1.5 meters. The Vetiver was planted in July/2008 and completed by December/2008 (Fig. 5).

The land between the Vetiver hedgerows was totally covered with mulch (straw and sawdust: 0,5 kg/m^2) and jute bags to improve the soil roughness between the contour lines.

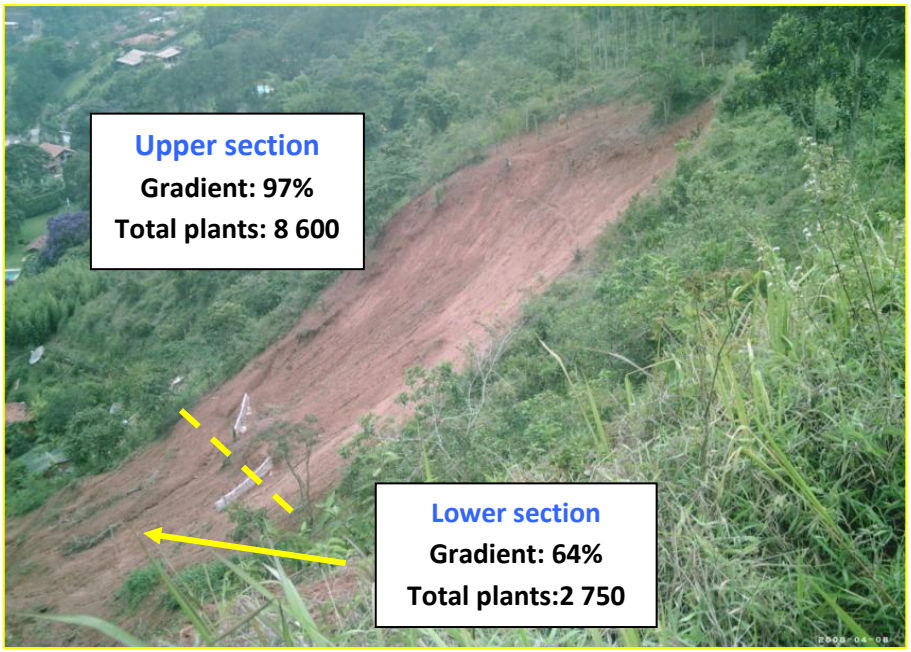
In the next two years (2009 and 2010), 2.300 additional slips of Vetiver were planted to improve protection.

Fig 5. Contour rows planted at VI between 1 and 1.5m

Total Plant Number

The total plant number used for both sections, including replanting for maintenance was 8 600 plants for the upper section and 2 750 for the lower section (Fig.6).

Fig 6. Total plant number used for both sections



Drainage

Shallow and surface drainage is very important in reducing pore pressure of the surface soil layer. The surface drainage was completed in September/2009. Until June 2011, 450 additional slips were planted as a “live nail”.

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. Today 95% of the area is fully covered with vegetation (Fig.7).

Fig 7. Shrub and fruit tress planted in inter spaces on lower slope

RESULTS TO DATE

Sediment Trapping

Before entering the public drainage line the runoff water was collected and passing through nine sediment boxes, to separate water from silt material. Water quality monitoring showed the water discharged into the public drainage line is clean, with no sediment in it, indicating the soil on the slope has remained stable and fully stabilised.

Stabilisation and Rehabilitation

After three years since the landslide, although suffering strong winds and heavy rains, the hill slope remained fully intact with the help of the Vetiver, which is now fully grown and mature, and firmly holding the soil (Figs.8 and 9).

Fig.8: Lower part of the slope

Fig.9: Upper part of the slope

This effective slope stabilization and the mulch reduced sediment runoff provides a real life testimony for Vetiver which thus far remains in great condition.The ultimate test on January 11 and 12, 2011, when after an initial 18 mm it rained 95 mm

over a two and half hour period. All together 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 (concentrated in the last few days of the month) and during the week before January 11, 2011 the precipitation was 60 mm, and the slope remained intact thanks to the "Soil Nails" and "Green wall" (Fig.10). In December 2010, 2 years after planting, root depth measured at three points along the slope were 2m-2.5m deep into the soil mass, but most impressively is the fantastic root network between the plants.

Fig.10: "Soil Nails" and the green wall

Maintenance

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

The Cost

The cost of the Vetiver solution was no more than 29 000 USD, proteting an area of 1840 square meters. About US$ 16 per square meter or USD 1.6/square feet. The cost included all expenses with materials and labour, including insurance, meal, extra hours, topographic study, tubes of draining, boxes, eucalyptus poles for support of retaining wall etc.

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

OTHER CONSIDERATIONS

The Vetiver solution can be complementary to other slope stabilization methods. For instance the soil/cement, 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. When planting 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. In the present application, to reduce the gradient on the lower part of the slope, four retaining walls of 1m high each reinforced with soil/cement were built.

Figs.11 shows the before and after scene of a properly installed wall incorporated with vetiver planting.

Fig.11: Before and after

RECOMMENDATIONS

- The use of VS for the stabilization of slopes not steeper than 1:1 (H:V) when implemented appropriately, using mature slips and planted properly in both direction, horizontal (10cm between slips) and Vertical Interval, (VI=1m -1,5m) between rows and about 2 slips/m^2 as "live nail" on the inter row space, can assure stability of the slope, even after landslide occurred on the slope.

- The basic design is to reduce the kinetic energy of runoff, which creates an adverse effect on natural soil nailing. With vetiver planting a grid of its roots acts as a true set of "nails" holding the soil mass, preventing incremental erosion and reducing the chance of pockets of water on the slope that may result in high hydraulic pressures leading to slippage. The roots of *Vetiver 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).
- Vetiver System Technology is a cheap, effective and safe solution for the rehabilitation of landslides and reduction of landslips incidence in high rainfall region
- This work clearly demonstrated the real potential of the VST in mitigating the effects of the climate changes that currently provokes the natural disasters on the environment, as it happened here.

CONCLUSION

- 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 effectec by landslides. This is due to properties of having strong and lengthy roots, equivalent to an engineer's soil nail.
- The VS will fail when not properly applied or not well maintained. The Vetiver when installed and following the correct technical guidelines is a guaranteeed success.
- Perhaps the only real defect of the Vetiver solution is: ***Too cheap to be true, too cheap to believe when compared to heavy stone structures.***
- Here is the final living proof

April 2008 **January 2011**

SPECIAL THANKS

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