CSR-EMP integration through implementation of Vetiver Technology for Environmental Management

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Vetiver Grass Technology has been proved to be the most effective bioremediation for protection of soil slopes from erosion . About 100 countries from Asia, Africa and the USA have used this low cost, environmentally sustainable and community friendly solution to many challenging sites. Very good results have been demonstrated in Erosion control of Hill slopes and river banks in Assam. It has also been found useful in stabilization of slopes at bridge approaches.

Surface mines have the following challenges that can be addressed using vetiver technology:

1. Stabilization of spoil dumps
2. Erosion from broken areas, spoil dumps and release of siltation load to the water courses in the catchment areas
3. Toxic water in tailing dams
4. Rehabilitation of project affected people. The neighboring villagers need to have economic activities after mine closure, demands for domestic fuel leading to deforestation and hindrance to forest restoration programme.

If properly planned and implemented with close monitoring, this plant can help in complying with the CSR and EMP requirements in a surface mine.

Slope Stabilization Process

The full process of stabilization involves:

- propagation of the plants in a nursery,
- preparing the slopes,
- planting onto the slopes
- maintenance prior to the monsoon season

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It is necessary to undertake a demonstration experiment to confirms that the vetiver system can be used in surface mines for control of erosion on spoil dump slopes and road embankments, increasing of green coverage.
The vetiver system can be used alone or in combination with traditional engineering approaches of terracing, geotextiling etc.

The Vetiver grass, a C4 plant, can absorb about 1.5 kg carbon per plant per year. The vetiver can eliminate protective walls that require boulder or stones preparation and construction of which consumes more energy. Thus vetiver helps in CO_2 sequestrtion and reduction of fuel consumption in the mines.

Erosion in Surface Mines

Erosion from spoil dumps in surface mines lead to:

1. Sedimentation in the nallas and rivers
2. Alters the characteristics of the catchment area
3. Gully formation in the spoil dumps
4. Slope failure and slides
5.

In protecting the spoil dumps from erosion geotextile is often used, however it is very costly. Moreover performance is also not consistent. It is always better to have a solution to erosion problems that could generate other economic, social and environmental benefit. The hard engineering solution to erosion is providing retention wall, gabion and diversion channels, which incur high financial and environmental costs, and often give limited success.
In such scenario vetiver grass can be a panacea.

Traditional “Hard” Engineering approach for erosion control will require:

- Concrete and stone rip-rap,
- Stone filled gabion baskets,
- Masonry walls

These involve use of stone, cement and steel, and need to be transported from their sources through involvement of number of transfers at different distances. Thus these methods are costly and release environmental pollutants of different forms at different stage. In other words, the traditional solution to erosion protection has very high energy footprint and contribute to global warming.

Vetiver for Spoil Dump Management

The commonly known vetiver grass is the plant known to the botanist as Chrysopogon zizanioides (figure 1). The plant develops its typical root system (Figure 2) that may grow more than 6 feet.

Figure 1 Vetiver grass

Figure 2 Vetiver roots

Vetiver was promoted to help conserve soil and water for agriculture by the World Bank in the 1980's and 1990's (Greenfield 1989 and National Research Council 1993), evolved in the late 1990's to become an important soil bioengineering tool. The benchmark experiments on vetiver root strength in 1996 were an important step towards its wider acceptance. The experiments confirmed a mean tensile strength of some 75MPa at 0.7- 0.8mm root diameter (Hengchaovanich and Nilaweera, 1996). The roots of vetiver grow rapidly and can achieve a depth of 3m in one year. Vetiver can grow in adverse soil conditions and extreme climatic conditions (Truong 1996). The vetiver system has become a field tested, economical, environment and community friendly, sustainable system for erosion control on slopes and in drainage systems. Vetiver grass has particular properties that make it uniquely suitable for soil erosion protection by breaking the cyclic process of erosion. The Vetiver system can be summarized as below:

The Vetiver System (VS):

- VS consists of a simple vegetative barrier (a hedge) comprising upright, rigid, dense and deeply rooted clump grass, that slows runoff, allowing sediments to stay on site, eventually forming natural terraces.
- It has been used for more than a century in many Asian, African, and Caribbean countries as a traditional "soil binding" technology.
- VS is used for soil and moisture conservation, bioengineering, and for bioremediation.
- Hedges are propagated and established vegetatively. Analyses show that recommended cultivars of Chrysopogon zizanioides (south India type) are sterile and are not invasive
- Vetiver's deep, massive fibrous root system can reach down to two to three meters in the first year.
- This massive root system is likened to "living nails", binding the soil together.
- The measured maximum resistance of vetiver roots in soils is equivalent to one-sixth that of mild steel (75 Mpa); stronger than most tree roots; improves soil shear strength by as much as 39%
- The fibrous mat of roots strengthens earthen structures and removes many contaminants from soil and soil water.
- Closely planted slips grow into dense hedgerows with a deep, tough root systems. They can withstand inundation, and effectively reduce flow velocities, forming excellent filters that prevent soil loss.
- It is perennial and permanent, capable of surviving as a dense hedge for decades, but only growing where we plant it.
- It exhibits xerophytic and hydrophytic characteristics if it is to survive the extremes of nature. Vetiver grass, once established, is little affected and highly tolerant of droughts or floods.
- It has a deep penetrating root system, capable of withstanding tunneling and cracking characteristics of soils, and should the potential to penetrate vertically below the plant to at least three meters.
- It is capable of growing in extreme soil types, regardless of nutrient status, pH, sodicity, acid sulphate or salinity, and toxic minerals. This includes sands, shales, gravels, mine tailings, and even more toxic soils.
- It is capable of developing new roots from nodes when buried by trapped sediment, and continue to grow upward with the rising surface level, forming natural terraces.
- It does not compete with the crop plants it is protecting.
- It is not a host (or intermediate host) for undesirable pests or diseases of any other plants.
- It is capable of growing in a wide range of climates -- from 300 mm of rainfall to over 6,000 mm; from sub-zero air temperatures (where the soil does not freeze) to more than 55º C. It is also able to withstand long and sustained droughts (> 4 months).

- It is cheap and easy to establish as a hedge and easily maintained by the user at little cost.
- It is easily removed when no longer required.

Effect of Vetiver grass on erosion control.

The occurrence of erosion can be briefly described as comprising of the following three phenomena:

1. Sub aerial preparation
2. Particle entrainment
3. Mass failure

The forces involved are shown in Figure 3

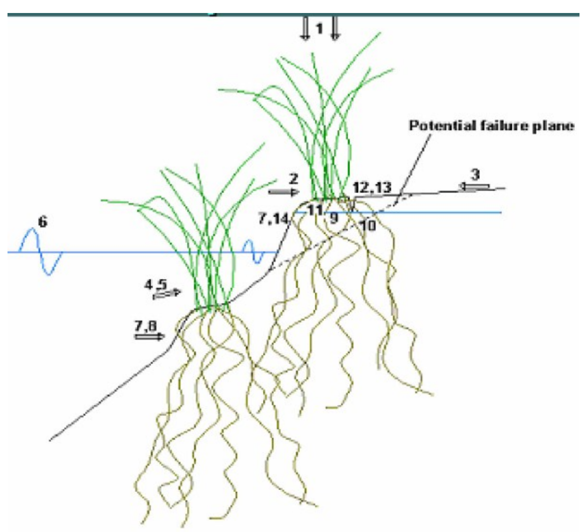

Figure 3 Vetiver for erosion control

Sub aerial preparation is shown in the figure by 1,2 and 3. 1 shows that the canopy intercepts rainfall, which dissipates raindrop energy and reduces rainfall available for infiltration. 2 indicates that the canopy reduces wind erosion by stabilizing the surface and decreasing near-surface wind velocities, however, the canopy exposed to wind transmit dynamic forces into the slope. 3 shows that the stems reduce run-off erosion by reducing flow velocities but at the same time increase infiltration

The labels 4 to 8 show the **Particle entrainment** by vetiver system. 4 shows that a portion of the canopy (termed as submerged canopy) reduces near-bank flow velocities. 5 indicates that this submerged canopy damps turbulence, which results in a reduction of peak shear stresses. 6 Submerged canopies, especially the stems dissipate wave energy. 7 shows that the root system physically restrains soil particles. The root system provide an apparent cohesion, which increases critical shear stress (8).

Mass failure prevention by vetiver is shown in 9. The vetiver root system increases drainage and permeability which results in a decrease of excess pore pressures. The root system increases soil shear strength via apparent cohesion and therefore the probability of the occurrence of a andslide is reduced (10). 11 shows the decayed roots that reduce cohesion. Depletion of soil moisture (12) may increase desiccation cracking in the soil, resulting in higher infiltration capacity. The tensile strength of the roots delay crack forming (13) as well as prevents pushing off aggregates of soil(14).
Vetiver has been proved to have the highest strength of all grasses. Figure 5 shows the Root and the root matrix of this grass.

Slope Stability and Root Strength

Shallow slips of 1-1.5 m, comprise the majority of problems faced by most people after slope formation, especially in regions with prolonged and high rainfall. This problem still arises despite the fact that slope analysis might have shown a slope to have adequate overall factor of safety. To tackle this problem, engineers conventionally rely on the use of 'hard' or 'inert' material such as mortared riprap, shotcrete or the like to seal off the slope to prevent water infiltration that is deemed to be the cause of the slippage in the first place. However, not in all cases they succeed. An alternative solution, as mentioned in the Introduction, is to resort to vegetation, in this case vetiver, to help strengthen the surficial 1-1.5 m layer that is prone to slippage.

How vetiver roots help in the strengthening the outer zone is explained diagrammatically in Figure 4:

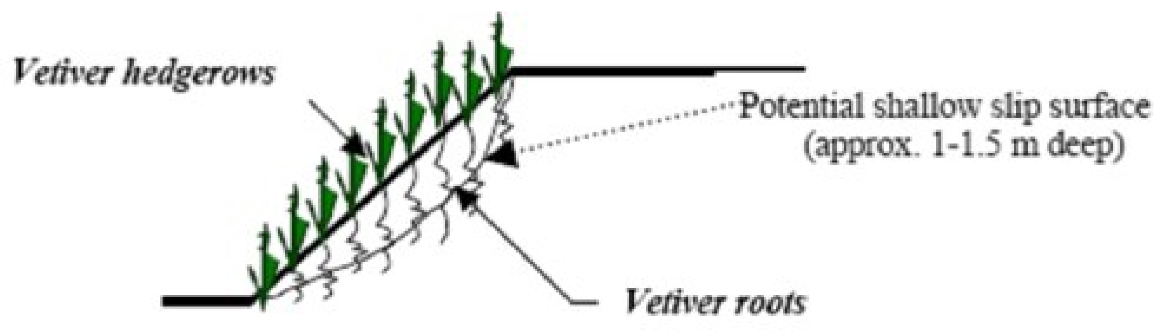

Figure 4 Soil stabilization mechanism by vetiver (after Hengchavanich, D, 1996[3])

When vetiver roots interact with the soil in which it is grown, a new composite material comprising roots with high tensile strength and adhesion embedded in a matrix of lower tensile strength is formed. Vetiver roots reinforce a soil by transfer of shear stress in the soil matrix to tensile inclusions. In other words, the shear strength of the soil is enhanced by the root matrix

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[3] Hengchaovanich, D. and Nilaweera, N.S. (1996). An assessment of strength properties of vetiver grass roots in relation to slope stabilization. Proc. First International Vetiver Conf. Thailand pp. 153-8.

(Styczen and Morgan, 1995). As mentioned in the introduction, vetiver roots are very strong with high mean tensile strength of 75 MPa or approximately 1/6th of strength of mild steel. When the dense and massive root networks act in unison, they resemble the behavior of soil nails normally used in civil engineering works. With its innate power to penetrate through hardpans or rocky layers, the action of vetiver roots is analogically likened to 'living soil nails' by the Hengchaovanich . Cheng et al. (2003) supplemented the root strength research by conducting further tests on other herbs (grasses) as tabulated below (Table 1) As is obvious, vetiver has the highest strength of all grasses.

Fig. 5 : The Root and the root matrix

Table 1 Diameter and tensile strength of root of various herbs

Grass	Avg diam. of roots (mm)	Avg tensile strength (MPa)
Late Juncellus	0.38±0.43	24.50±4.2
Dallis grass	0.92±0.28	19.74±3.00
White Clover	0.91±0.11	24.64±3.36
Vetiver grass	0.66±0.32	85.10±31.2
Common Centipede grass	0.66±0.05	27.30±1.74
Bahia grass	0.73±0.07	19.23±3.59
Manila grass	0.77±0.67	17.55±2.85
Bermuda grass	0.99±0.17	13.45±2.18

Examples of Vetiver Applications

The effect of vetiver on prevention of erosion can be seen in following figures.

Figure 6 Slope before plantation, plantation of vetiver and after 3 months.

Figure 7 Effect of vetiver in preventing erosion and slope failure.

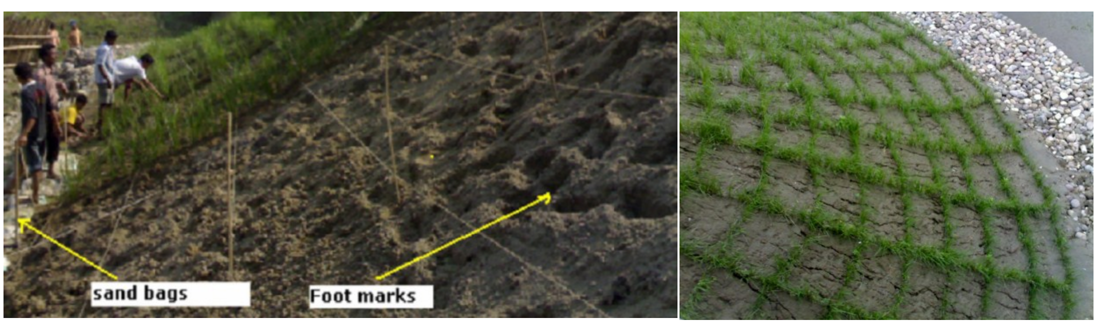

Figure 8 Slope Plantation

In the plantation areas of KIOM and MIOM the improvement of soil quality and to increase the green coverage a proposed scheme is shown in Figure 9.

Figure 9 Recommended vetiver grass plantation for erosion control cum soil management

Suggestions for plantation

Care must be taken to selelct the site for plantation. The weight of the grass after growing should not adversely affect the stability of the slope and cause slides. Normally for plantation in the field the following points should be noted:

- Potted/pouched plants have shorter stress period and hence grow quicker and healthier than bare rooted slips. This was corroborated from results of other projects also.
- Large slope should be provided with intermediate benches. Vetiver Network recommends benches every 5m vertical distance
- The plants should be pruned to encourage lateral growth and to reduce the canopy. This exposes the slope surface to enhanced evaporation thus quicker release of trapped water.
- The top rows on the slopes should be dense to dissipate the energy of the run-off. Hence the planting should not be more than 10 cm apart.
- On unconsolidated fills, the Vetiver plants themselves should be protected against erosion during the initial period by bamboo palisades/ sand bags.

CSR and Vetiver

Under CSR, it is attempted that the neighboring villages get boosting in their economic, energy and environmental demands. Vetiver has number of rural use:

1. Tratch for roof
2. Cattle feed

3. Domestic fuel (mixed with cowdung)
4. Raw materials for artifacts
5. Cleaning of water bodies with objectionable DOD and COD.

The society is benefitted from vetiver by:

- Saving the soil- the greatest asset of the earth- from erosion
- Improving agricultural productivity Increasing soil fertility
- Facilitating growth of local vegetation
- Pest control
- Increasing Soil Moisture Retention

It can provide the villagers:

1. Fuel
2. Income generation
3. erosion
4. Improve agricultural productivity
5. Increasing soil fertility
6. Facilitating growth of local vegetation
7. Pest control and avoid loss of crops
8. Increases Soil Moisture Retention


Figure 10 Vetiver assisted agriculture product

In agriculture, vegetable beds produce more when vetiver is planted along borders (figure 10) and use of Vetiver mulch conserves moisture and improves soil fertility. The community can increase their earning by practicing organic farming. (Figure 11).

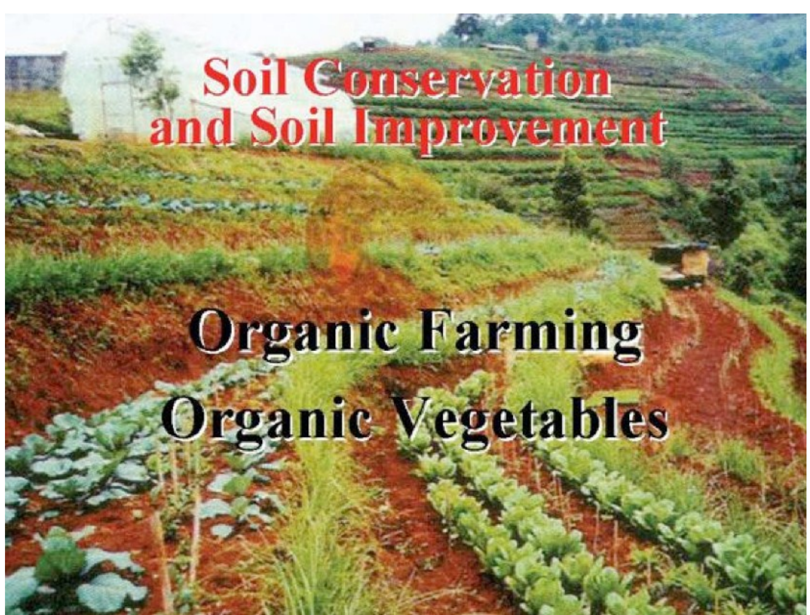

Figure 11 Vetiver for organic farming in Thailand.

Vetiver can be be briquetted and cn be converted to charcoal through flash carbonization and thus contributes to production of fuel.

Properly trained people can get international market for selling their domestic products of vetiver handicrafts. (Figure 12)

Figure 12 Handicrafts with Vetiver.

Conclusions :

Vetiver is ideal plant for bioengineering because it has

- long, strong and abundant root matrix.
- ability to grow as a dense hedge
- very quick growth
- ability to grow almost everywhere
- high threshold limits against toxicity
- high biomass below ground, low biomass above ground
- non invasive nature, so that the local ecology is not disrupted
- survival capacity as perennial and permanent
- xerophytic and hydrophytic characteristics
- no competition with the crop plants that it may protect.
- Capability to fight against pests and diseases.

The vetiver will be able to help

- To stabilizes overburden/ tailing dumps
- To stop surface erosion/rill & gully formation
- To reduce heavy metal contamination
- through phyto remediation and soil stabilization

- to reduce surface run-off, increases ground water recharge
- to acts as a pioneer plant in the wasteland
- to the growth of local vegetation

Thus it is proposed that a project should be initiated to integrate CSR and EMP using the vetiver technology for a long term environmental management with involvement of local people.

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