Use of Vetiver as Soil Bioengineering Structure for Stabilization of Landslides-scarred areas in the Cameroon: A Pilot Project.

Introduction

Soil bioengineering structure is the application of living plants to perform engineering functions (Oku and Aiyelari, 2011). Soil bioengineering techniques used in combination with civil and social engineering measures can reduce the overall cost of landslide mitigation considerably (Singh 2010). Reports from Truong (1999) and Shrestha et al., (2012), showed soil bioengineering offers an environmentally friendly and highly cost and time effective solution to slope instability problems in mountainous and hilly areas and is a technique of choice to control soil erosion, slope failure, landslides, and debris flows. One of the major differences between physical engineering construction techniques and soil bioengineering is that physical structures provide immediate protection, whereas vegetation needs time to reach maximum strength. Thus the combination of physical and vegetative measures offers a combination of immediate and long-term protection, as well as mitigation of the ecological damaging effects of some physical constructions (Shrestha et al., 2012)

A landslide is the downslope movement of a mass of soil or rock/debris or both (Highland and Peter, 2008). The event of landslide or slope failure occurs worldwide in various forms (Plate 1. fall; Plate 2. topple; Plate 3. slide/slump; Plate 4: spread and Plate 5: flow) as a disaster. Disasters, are events that cause injury and death or economic losses that exceed the coping capacity of the affected people or region, creating a need for outside assistance (Norman and Alkema (2011). According to the Center for Research on the Epidemiology of Disasters (CRED, Belgium; http://www.cred.be/), an event needs to satisfy at least one of the following criteria to be considered a disaster: 10 or more people reported killed, at last 100 people affected, a state of emergency declared, or a call for international assistance issued. Cameroon has witnessed a number of the landslide disasters in the last twenty years which has led to loss of lives, infrastructure, farmlands, leaving many homeless with trail of poverty and hardship. Although landslide or slope failure is classified as geological erosion, human land use practices

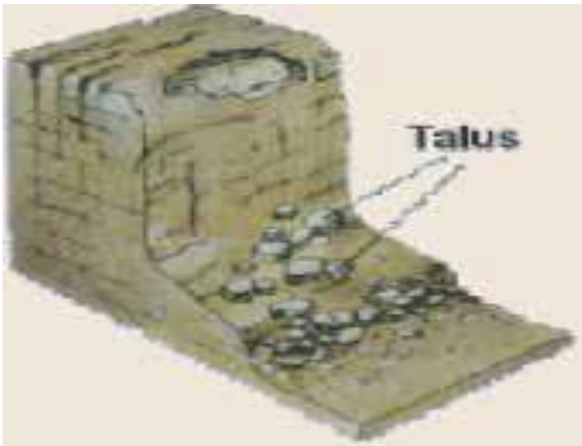

Plate 1. Fall

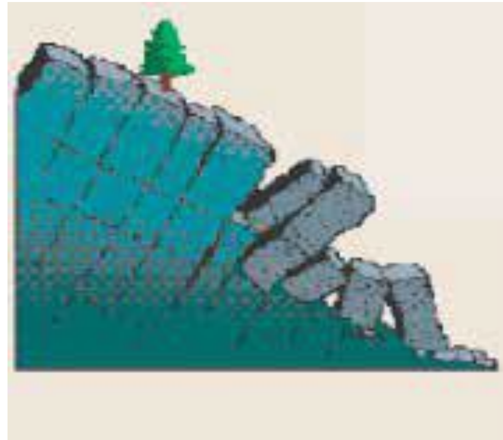

Plate 2. Topple

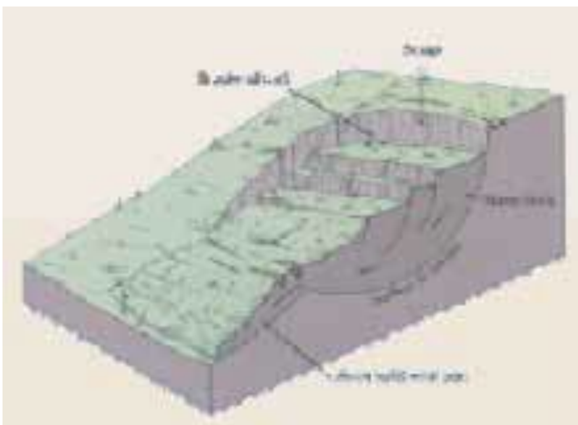

Plate 3. Slide/slump

Plate 5. Spread

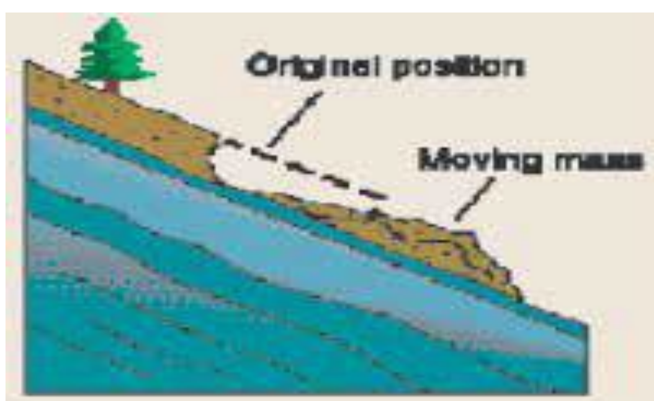

Plate 5. Flow

play a major role in slope processes with the combination of uncontrollable natural events as earthquake, heavy rainstorms etc. Truong et al., (2008). Analysis the landslides in Cameroon had been documented with some being of hydrological, seismic and tectonic origin (Ayonhge et al., 2002), most are triggered principally by heavy rainfall (Suh et al., 2003; Diko, 2003, Che et al., 2011). The physics of landslide or slope failure are well known (Li and Clarke 2007; Truong et al., 2008). Slope saturation with water is a primary cause of the landslide. It will occur when the slope safety factor (SF) < 1 and one of the chief drivers (heavy rainstorm) is present.

From Wikipedia (nd) reports, the climate of the Cameroon is tropical, in the highlands in the interior (with altitudes ranging from 1,000 to 1,500 m above sea level), the mean annual temperature is around 22° C, and annual rainfall averages between 1,500 and 1,600 mm. This is where the transition takes place from the savanna scrub in the north to the rainforest in the south. In the mountains to the west, rainfall levels vary from 2,000 to 11,000 mm per year. The region in the southern foothills of Mount Cameroon has a mean annual rainfall of 11,000 mm per year, and is recorded as one of the wettest places on earth (Martin 2013). In both of these regions there is a "dry" season between December and February, though a certain amount of rain can still fall during this period. The climate of the coastal region in the south is equatorial, with annual rainfall of between 1,500 and 2,000 mm and a mean annual temperature of 25° C. This region is covered in dense tropical rainforest, and the drier months are December and January. (Martin, 2013). Such high rainfall amount recorded with its intensities indicate rainstorms are not only heavy, but violent and described as 'toad stranglers' and gully washers. This explains the area's slope inability and its proneness to landslide or slope failure. As climate change intensifies, temperatures and rainfall amounts and intensities will also increase (active factors in rock weathering). This will render even stable, but unfortified slopes unstable. This justifies the need for increasing the slope Safety Factor (SF) through application of vetiver system.

Cameroon according to Ngole et al., (2007), is less equipped technically and financially to handle natural hazard. The effects of such disaster as landslide are always greater on the economy and welfare of the citizens (Barro, 2009; Diko, 2012). Like any other African country, this disaster will always challenge the Cameroon's government's ability to solve it as the solution is often complex and financially costly giving the Country's resources with the other competing sector of the economy. According to Bhattacharyya (2006); Truong, (1999); Truong et al., (2008) and Grimshaw (2008) reports, using nature to combat nature provide better solution to natural problems. Applying engineering to the gifts of nature to solve problems is today's engineering philosophy. Soil bioengineering, using vetiver, caught the attention of the World Bank since 1986. Initially the World Bank promoted the use of vetiver through its vetiver department and now the The Vetiver Network International (TVNI). Vetiver grass when planted on the contour at appropriate distance has influence in providing stabilization to the slope and rehabilitating of the affected ones. Vetiver has successfully been used in stabilization works on slope lands in Thailand, Venezula, Vietnam, Phillpines, India, China, Brazil, Ethiopia, Sri Lanka and Central America. In Thailand it is a government policy that use of vetiver becomes an approach to infrastructure protection and it is applied on a large scale (PDPB, 2000).

In the mechanics of the slope stabilization against landslide when vetiver is used, 1) delay and spread runoff flow, thus increasing infiltration what may have contributed to the landslide; 2) it also reduces the speed of the subsurface flows reducing erosion process thus avoiding the activation of the landslide process; 3) where rock is fractured underneath, vetiver will work as anchors. Engineers liken the vetiver root to a 'Living Soil Nail'. The root has a mean tested tensile strength of 75 MPa which is 1/6 strength of mild steel reinforcement and a shear strength increment of 39 % at a depth of 0.5 m. As in civil engineering works where the soil is bind together using soil nail. Vetiver as a living soil nail once established binds the soil particles together. (Hengchaovanich and Nilaweera, 1998; Hengchaovanich, 1999). Vetiver improves the shear strength of the soil thereby preventing it from sliding or slumping (Truong, et al., (2008).

The use of vetiver system technology is not new in Cameroon as it was used in the Northwest Province of Cameroon for contour farming (Pinners 2000). Vetiver provides a natural, environmentally-friendly and effective way to stabilize landslide prone lands. In contrast to conventional engineering structures, vetiver grass technology has been 'standalone' and providing total protection where engineering structures had failed as in the Itaipava Petropolis landslides slope stabilization and rehabilitation (Eboli et al (2011); Bhattacharyya (2006). The advantage of vetiver as a soil bioengineering structure is once established, the vetiver plantings will last for decades with little or no maintenance.

Objectives of the project

1. To source and raise vetiver (*Chrysopogon zizanioides*) multiplication nursery in Cameroon.
2. To increase stability of slope using vetiver as soil bioengineering structure so as to prevent it sliding or slumping

3. To use vetiver as a bioengineering structure for the rehabilitation and correction of failed slopes.
4. To use of the vetiver in slope stabilization for prevention of landslides.
5. To mobilize the community members for participation with the organization of a Participatory vetiver Technology Development Workshops (PVSDW).

Expected results/outcomes.

- Stabilization of slope by increasing its stability using vetiver as bio-engineering structure.
- Eliminating and curtailing of landslide disasters on the stabilized slope.
- Fortification of rehabilitation works on landslide sites.
- Improvement of the vegetative covers of the sites following vetiver intervention.

Activities

Activities will be based on preventing landslides and increasing slope stability which is considered more cost effective than correction of slope after a landslide disaster. The activities will include;

- Mobilization of the community members and assembling of Project Team comprising of Community Members and faculty members in Geo-information Science, Soil Science, Geology, Agronomy, Sociology, Civil Engineering from the United Nations University – Institute of Natural Resources for Africa, head office in Accra, Ghana and its Operating Unit, the University of Yaounde′ 1, the Government agency responsible for Disaster Management, Forestry and Agriculture.
- Source for *Chrysopogon zizanioides* (vetiver *spp*) slips from the The Vetiver Network International (TVNI). The splits will be multiplied in the nursery to be located near the sites of application.
- Identification of prospective slope failure through the study of satellite images to locate previous landslide or slope failure sites and conducting field investigation of potentially unstable slopes.
- Identification of potential mass-wasting areas by steep slopes, water seepage from side slope etc

- Participatory Vetiver System Development Workshop (PVSDW) shall be held to sensitize, educate and mobilize the community members (primary stakeholders) and government officials (secondary stakeholders) for the use of this bioengineering approach and its effectiveness.
- Site stabilization works will be carried out by the Community members and the Project Team

Sustainability of the project.

- Vetiver System requires maintenance programme in the first one year for proper establishment. Once established, it is virtually maintenance-free and last for decades. Therefore, the use of vetiver is particularly well suited to remote areas where maintenance could be costly and difficult.
- Vetiver improves the recovering of the sites to native and volunteer plants, fruit trees and other multipurpose tree species can be planted between the vetiver buffers from the second or third year after the full establishment of vetiver for the community use.
- Community members can prun the vetiver quarterly and the pruns used for house thatching, handicraft if learnt, compost for farming or substrate for mushroom cultivation.

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Use of indigenous vetiver grass species (*Chrysopogon nigritana* Benth Stapf) in the Rehabilitation of Copper Tailings in Zambia: a screen house and field project.

Background

Zambia's major economic activity is mining. This will continue even in the foreseeable future with the large deposits of copper, coal, gold, lead, zinc, cobalt etc. The copper mining is currently the country's economic lifeblood and a key employer of the southern African country of about 13 million people as it is the Africa's top copper producer (Bantubonse, 2010). Mining activity generates revenue, create wealth and improves standard of living but leaves behind lots of harmful waste materials with long term destruction of the physical, chemical properties and biological lives (natural ecological engineers and ecosystem purifiers) in the soil. Mining activity in Zambia raises serious environmental concerns. Sikaundi (2012) reported some of these environmental concerns are mine waste which includes tailings. Copper tailings are waste materials produced from concentrates with a copper content of less than 1 % and covers about 9,125 ha of land in Zambia (Sikaundi, 2005). This figure must have triple considering the number of copper mining companies in 2005 and 2012. Mine tailings generally pollute land and water resources as they are very high in their heavy metal contents which affect flora, fauna and human within the vicinity (Truong, 1999). From Truong (1999) report, concerns about the spreading of these contaminants have resulted in strict guidelines being set to prevent the increasing concentrations of heavy metal pollutants. In some cases industrial and mining projects have been stopped until appropriate methods of decontamination or rehabilitation have been implemented at the source. This can not be the case in Zambia as the economy depends on the copper mining sector. Conventional method of treating this copper tailing waste is expensive and near impossible to carry out, when the ha of land affected and the volume of the waste is considered as it cannot be economically treated or removed. On the other hand, off-site contamination through wind and water erosion must be prevented. Vegetative methods remain the most practical and economical cleanup method. The revegetation of the contaminated lands is often difficult and slow due to the hostile growing conditions present which include toxic levels of heavy metals. According to Raskin and Ensley (2000) and Roongtanakiat (2001), the potentials of a plant for rehabilitation of mining fields/tailings depends on the tolerance of the plant to contaminants such as heavy metals. Vetiver grass suits here due to its unique morphological and physiological characteristics. Which has been widely known for its effectiveness in erosion and sediment control (Greenfield 1989), has also been found to be highly tolerant of extreme soil conditions including heavy metal contaminations (Truong and Baker 1998). *Chrysopozon zizanioide,* a species of vetiver, a non evasive plant predominantly found in Australia and Asia has effectively been used in rehabilitating mining sites/soils heavily polluted with heavy metals with documentation in the literatures (Truong and Baker, 1998; Truong 1999 Roongtanakiat and Chairoj, 2001a,b). It was highly successful in the rehabilitation of bentonite tailings which are extremely sodic (ESP 48 %) and alkaline (9.0). Also in northern Queensland, Chrysopozon zizanioides was successful in the rehabilitation of alluvial gold tailing that was having very high arsenic and cadmium content (Truong, 1999; Troung et al., 2008). Chrysopozon nemoralis, a species of vetiver found in Vietnam has been reported to be less effective in mine rehabilitation when compared with Chrysopozon zizanioides (Truong et al., 2008). This gives an indication that all species of vetiver do not have the same land/soil rehabilitation and restoration ability. *Chrysopozon nigritana* is a species of vetiver found predominantly in Africa and native to west and southern parts of Africa (Truong et al., 2008). It grows in the wild in most countries of Africa. The ability of this indigenous vetiver species in rehabilitation of mine tailings has not been reported perhaps because the use of Vetiver in Africa is still in its infancy. On the other hand the superior effectiveness of this indigenous vetiver species (Chrysopogon nigritana) in rehabilitating degraded erosion prone steep lands in Nigeria when compared to use of organic manure performance has been reported (Oku et al., 2011). In this study, vetiver enhanced the soil properties much better when it was assessed five years after the vetiver and organic manure intervention. This performance of the indigenous *Chrysopozon nigritana* compares with reports on *Chrysopozon zizanioides* in Asia under similar conditions. A plan to rehabilitate polluted land using Eco-technology should be with a non invasive native plant species. Rehabilitating the soil, preventing further off-site pollution of water bodies by this leachate and bringing back biological lives to the lands polluted by tailings will require removing the heavy metals. This process will at the same time rebuild the soil organic content and fertility levels. This is requisite for any sustainable reintroduction of crops or activities either naturally or artificially. The hypothesis in that the Africa's indigenous vetiver species (Chrysopogon nigritana) will effectively rehabilitate copper tailings as the species in Australia and Asia (*Chrysopogon zizanioides*).

Objectives of the project

Short term

1. To evaluate effectiveness of indigenous vetiver species in the rehabilitation of copper tailings in the field.

2. To compare the effectiveness of the Africa's indigenous vetiver species (*Chrysopogon nigritana*) with the South Indian species (*Chrysopogon zizanioides*) in the screen house.

3. To plant some short cycle agricultural crops using the soil and determine the heavy metal uptake in the crops before and after rehabilitation and compare it with the standard human/health safety threshold levels. You should include Mung beean if possible to compare with some Indian works, if no Mung bean then another popular bean grown for food in the region

4. To scale up the rehabilitation project to cover the country through government policy intervention.

Long term

To restore the mine contaminated land in Zambia using vetiver system – an environmental friendly, replicable, cheap and effective eco-technology.

Activities/methodology

- Mobilization and assembly of the research team from Senior Researchers in Soil and Crop Sciences, Mining Science, Chemistry, and 2 postgraduates students (1 Msc and 1 PhD) from the University Nations University – Institute of Natural Resources for Africa

(UNU-INRA) Operating unit, the University of Zambia and the faculty member from the Head office of UNU-INRA in Accra, Ghana.

- Some slips of *Chrysopogaon zizanioides* will be sourced from The Vetiver Network International (TNVI) while the *Chrysopogon nigritana* will be sourced within Africa. The slips will be multiplied in the nursery within the Faculty of Agriculture of University of Zambia.

- Soils from contaminated sites will be brought to the screen house within the faculty of Agriculture and filled in a poly bag with known weight.

- Pre and post experimental heavy metals content and other chemical properties of the contaminated soils shall be determined in the laboratory using standard methods.

- In the screen house the 2 vetiver species will be planted in the polybags using the contaminated soils.

  The treatment will include;
  T_1 vetiver *spp* + soil only
  T_2 vetiver *spp* + soil + organic manure
  T3 vetiver *spp* + soil + moringa fresh leaves
  T4 vetiver *spp* + soil + moringa leaf powder
  T_5 vetiver *spp* + soil + moringa leaf extract
  The screen house trial will be laid in a randomized block design with ten treatments and 4 blocks.

- Vetiver leaves will be prune at 4 weeks interval and the soil sample for laboratory analysis of heavy metals uptake of vetiver and in the soil. This will be monitored for 16 weeks or 4 months. The heavy metal contents willl be compared with the allowable threshold levels of heavy metals for soils and human health. At the end of 16 weeks or 4 months the vetiver shall be uprooted. Soils with the desired or tolerance level of heavy metals will be planted to selected short duration agricultural crops. Survival and heavy metals uptake and accumulations in the crops will be determined through laboratory analysis. The data will be subject to statistical analysis to compare the performance of *Chrysopogaon zizanioides* and *Chrysopogon nigritana* in the clean up of copper tailings. The treatment with the best performance in the screen house trial will be adapted to the field on a large scale clean up and rehabilitation.

Expected results.

- Reduction in heavy metal contents of the soil to both the soil and human tolerance levels.

- Rejuvenation of soil biological lives of the formerly contaminated soil/land.
- Revegetation of the formerly contaminated soil/ lands with crops and volunteer plants.

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