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PRACTICAL USE OF THE VETIVER SYSTEM AS AN EFFECTIVE MULTI-APPLICATION BIO-ENGINEERING TOOL FOR SOIL AND WATER MANAGEMENT: IMPERATIVES FOR NIGERIA.

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ABSTRACT: At the heart of the Vetiver system (VS) is the plant - *Chrysopogon zizanioides* - formerly *Vetiveria zizanioides*. This plant, commonly known as Vetiver grass, is a clump grass that was first developed by the World Bank for soil and water conservation in India in the mid-1980s. Clones of Vetiver (*Chrysopogon zizanioides*), are sterile and non-invasive. It is these cultivars with names such as Sunshine and Monto that is promoted for use for the Vetiver system and is based on the application of some extraordinary features of the Vetiver grass which includes a massive and deep root system, tolerance to extreme climatic variations such as prolonged drought, flood, submergence, fire, frost and heat waves. It is also tolerant to a wide range of soil acidity, alkalinity, salinity, sodicity, agrochemicals and elevated levels of heavy metals in the soil. VS are now being widely used for soil and water conservation in more than 100 countries, thrive in Nigeria and may grow for at least 6 months a year. Previous researches have shown the VS to be very effective in soil and water conservation, infrastructure stabilization, flood control, water quality improvement, pollution control, land rehabilitation and disaster mitigation. This paper presents the special characteristics of Vetiver grass and its global uses for environmental protection. Potential applications of the VS in Mediterranean and Tropical climates, including Nigeria with imperatives for soil and water conservation in sloping lands, stream and levee bank stabilization, flood erosion control, offsite pollution control and disaster mitigation are discussed.

INTRODUCTION

It cannot be overemphasized that man continues to play a pivotal role in changing the world geography and environment. Obvious examples include the disruption of natural ecosystems to institute industrial processes, explosion of mountains to build roads, construction of dykes along rivers which creates large bowl of water storage comparable to a lake, or the destruction of forest resources to build houses and city-like complexes. Besides those, other causes include chemical changes in the atmosphere as a result of emission of gas or certain types of chemical substances, earthquakes, landslide and land subsidence, extinction of wild animal and plant species, massive flooding experienced in several parts of Nigeria as well as waves of extreme heat or drought which have occurred in several parts of the world. Critically negative environmental changes caused by man continue to exhibit huge impacts on human lives beyond control. Worst of all, one cannot anticipate the next possible disastrous outcomes of this ongoing life-ravaging situation. In response to this, different countries are earnestly trying to resolve or mitigate the problems by using several measures. Different methods including reliance on heavy machinery and cultivation of various crops have been attempted to resolve and prevent the problem. However, some of the methods incurred high costs and the technologies applied are too complicated for farmers to implement. Hence the need for the Vetiver system which is sustainable, reproducible, reliable, low-cost and above all environmentally-friendly in combating or militating against problematic issues related to soil and water management.

The use of vegetation as a bio-engineering tool for erosion control and slope stabilization has been implemented for centuries but its popularity has increased in the last decades. This is partly due to the low costs of bio-engineering techniques, and partly due to the fact that more knowledge and information on vegetation are now available for application in engineering designs. (Hengchaovanich, 1999).

Vetiver System (VS) prides itself on the use of Vetiver grass (*Chrysopogon zizanioides)*, which was first developed by the World Bank for soil and water conservation in Indian farmlands in the 1980s. Till date, it continues to create an enormous impact on agricultural lands such as surviving where other plants cannot, thus acting as a pioneer plant (Truong, 2004); establishing itself in hostile conditions and creating micro-climates that permit a variety of other indigenous plants to prosper. Scientific research conducted in the last 15 years has clearly demonstrated that VS has much wider applications owing to its unique morphological, physiological and ecological characteristics that permit it to adapt to a wide range of climatic and soil conditions (Truong, 2002).

The study aims at highlighting the practical use of the Vetiver system in other countries for soil and water management and in providing resilience against the consequences of environmental damage. It also throws light on researches on the Vetiver grass certifying the adaptability of the Vetiver system in Nigeria while drawing imperatives for the use of the Vetiver system in Nigeria for soil and water management.

Justification for a vegetative flow-through system as compared to the conventional engineering designs

The World Bank conducted a review to compare the effectiveness and practicality of different soil and water conservation systems and found that constructed measures though form a barrier across the slope, must be site specific, require detailed, accurate engineering design and regular maintenance. Most of the evidence also suggested that constructed works reduce soil losses and in have negative impact on soil moisture (Grimshaw, 1988). This leads to loss of water and sediments from the field as all runoff water is collected and concentrated in the waterways where most erosion occur in agricultural lands, particularly on sloping lands.

On the other hand, the vegetative conservation system needs to be planted on the contour and when that is done, it forms a protective barrier across the slope which slows the runoff water causing sediments to be deposited. This is known as the flow-through system as its barriers do not convey runoffs; rather they filter it as run-off water seeps through the edge without causing any erosion and without being concentrated in any particular area (Fig.1).

Ideally, species to be used as barriers for effective erosion and sediment control should have the following features (Smith and Srivastava, 1989).

- Form an erect, stiff and uniformly dense hedge so as to offer high resistance to overland water flow and have extensive and deep roots, which bind soil to prevent rilling and scouring near the barrier.
- Ability to survive moisture and nutrient stress and to re-establish top growth after rain.
- Minimum loss of crop yield implying that the barrier should not proliferate as a weed, not compete for moisture, nutrients and light and not be a host for pests and diseases.
- Preferably require only a narrow width to be effective and supply products of economic value to farmers.

Vetiver grass exhibits all these characteristics and it is unique in that it can thrive in arid and humid conditions, growing under some extreme soil conditions and survives wide temperature ranges (Grimshaw, 1988).

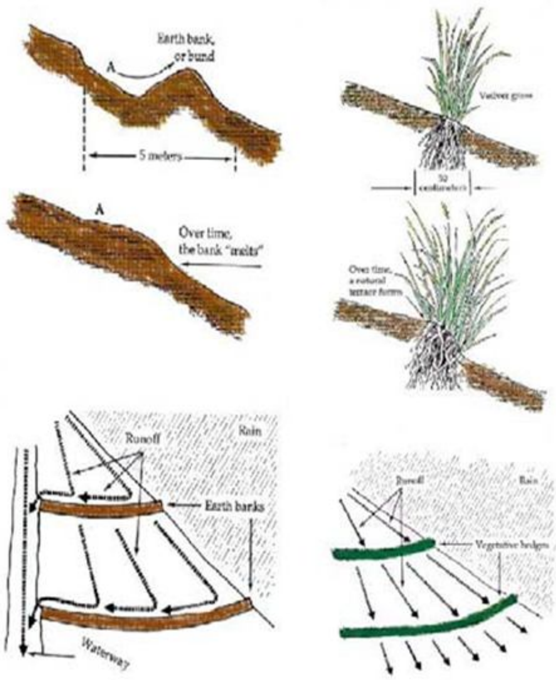

Figure 1: Comparison between conventional terrace/contour system and VS in soil and water conservation (Greenfield 1989).

Table 1: Comparism of the effectiveness and practicality of the constructed measures (conventional terrace / contour system) and vegetative flow-through soil conservation systems

	Constructed Measures	**Vegetative flow-through system**
1.	Forms a protective barrier across the slope which melts over time.	Forms a protective barrier across the slope which becomes a natural terrace over time as water seeps through the edge without causing any erosion and without being concentrated in any particular area.
2.	Unable to slow down run-off leading to loss of sediments as the runoff is collected by the artificial terraces and diverted as quickly as possible from the field to reduce its erosive potential.	Slows down the runoff water causing sediments to be deposited as the barriers do not convey runoffs; rather it filters it.
3.	Leads to loss of water from the field as runoffs are being diverted off the field	Conserves water as runoffs are slowed and re-absorbed by the soil.
4.	Wastage of land on the waterways due to its erosive potential	Does not allow for wastage of land all lands are maximally utilized.
5.	Must be site specific	Does not necessarily have to be site-specific. The roots could extend away from the original planting site.
6.	Requires detailed and accurate engineering and design.	Does not require much details and accurate engineering as it is easy to implement by farmers themselves.
7.	Requires regular maintenance	Once mature, some vegetation do not require maintenance anymore, e.g. *Chrysopogon zizanioides*

UNIQUE CHARACTERISTICS OF VETIVER GRASS

Morphological Characteristics

Vetiver grass has no stolons, very short rhizomes and a massive finely structured root system that can grow very fast, in some applications rooting depth can reach 3-4m in the first year. This deep root system makes Vetiver plant extremely drought tolerant and difficult to dislodge by strong current, Troung (1999). Stiff and erect stems, which can stand up to relatively deep water flow (Truong *et al.*, 1995). Highly resistance to pests, diseases and fire (Chen, 1999; West *et al.*, 1996). A dense hedge is formed when planted close together acting as a very effective sediment filter and water spreader (Dabney, 2000; Meyer *et al.*, 1996). New shoots develop from the underground crown making Vetiver resistant to fire, frosts, traffic and heavy grazing pressure (Troung and Loch, 2004). New roots grow from nodes when buried by trapped sediment. Vetiver will continue to grow up with the deposited silt eventually forming terraces, if trapped sediment is not removed (Truong *et al.*, (1995).

Physiological Characteristics

Tolerance to extreme climatic variation such as prolonged drought, flood, submergence and extreme temperature from -22^{o}C to 60 ^{o}C (Truong, 1999b; Xu and Zhang, 1999). Ability to re-grow very quickly after being affected by drought, frosts, salinity and adverse conditions after the weather improves or soil ameliorants added (Troung and Baker, 1998). Tolerance to wide range of soil pH (3.0 to 10.5) (Troung and Baker, 1998). High level of tolerance to herbicides and pesticides (Ciesiolka 1996; Cull *et al*., 2000; Pithong *et al*., 1996; Winter, 1999). Highly efficient in absorbing dissolved nutrients and heavy metals in polluted water (Suchada, 1996; Zheng *et al.*, 1997). Highly tolerant to growing medium high in acidity, alkalinity, salinity, sodicity and magnesium (Troung, 1994; Troung and Baker, 1996, Troung and Baker, 1998). Highly tolerant to Al, Mn and heavy metals such as As, Cd, Cr, Ni, Pb, Hg, Se and Zn in the soils (Troung and Baker, 1998 and Troung, 1999a).

Ecological Characteristics

Although Vetiver is very tolerant to some extreme soil and climatic conditions mentioned above, as a C4 plant it is intolerant to shading. Shading will reduce its growth and in extreme cases, may even eliminate Vetiver in the long term. Therefore Vetiver grows best in the open and weed control may be needed during establishment phase. On erodible or unstable ground Vetiver first reduces erosion, stabilises the erodible ground (particularly steep slopes), then improves its micro environment so other volunteered or sown plants can establish later. Because of these characteristics Vetiver can be considered as a nurse or pioneer plant on disturbed lands (Troung, 2000).

Genetic Characteristics

There are two *V. zizanioides* genotypes being used for soil and water conservation, and land stabilisation purposes: (Troung, 2000). The seeded north Indian genotype, the sterile or very low fertility south Indian genotype. While the seeded genotype is only used in northern India, the southern and sterile genotype is used for essential oil production around the world, and the latter is the genotype that is being used for soil and water conservation and land stabilisation purposes. Results of the Vetiver Identification Program, by DNA typing have shown that of the 60 samples submitted from 29 countries outside South Asia, 53 (88%) were a single clone of *V.zizanioides*. These 53 samples tested came from North and South America, Asia, Oceania and Africa and among these 53 cultivars are: Monto (Australia) and Sunshine (USA) (Adams and Daffom, 1997). Recent analysis have confirmed this distinction and shown a clear and replicable separation between the seedy and non fertile types (Adams pers.com).

Invasiveness Potential

It is imperative that any plants used for environmental protection will not become a weed. To comply with the very strict Australian rules on introduced plants, a sterile Vetiver cultivar was selected (from a number of existing cultivars in Australia) and exhaustively and rigorously tested for eight years for its sterility under various growing conditions. The Queensland Department of Primary Industries has approved this cultivar for use in soil conservation and it was registered in Australia as Monto Vetiver, which is identical to the Sunshine genotype used in the United States (Adams and Daffom, 1997).

In Fiji where Vetiver grass was introduced to the country for more than 100 years and it has been widely used for soil and water conservation purposes for more than 50 years, Vetiver grass has not become a weed in the new environment (Troung and Creighton, 1994).

In the US, although Vetiver has been in Louisiana for more than 150 years, it has not become a weed. Today, Vetiver can be found planted along the bank of many bayous and on old plantations where it has been essentially ignored since at least last century. There have been no reports of colonisation. Vetiver was also present in Florida for probably a century or more, it has never been reported as weed in cultivation (National Research Council, 1993). As a result of its infertility, Vetiver can only be vegetatively propagated and planted which is characteristic of non-fertile plants. Planting materials are obtained by sub-dividing the crown of a mature plant and are supplied as slips or splits in various forms suitable for different applications.

Although Vetiver grass is very resilient under the most adverse conditions it can be eliminated easily either by spraying with glyphosate herbicide (Bibhas *et al.*,1975) or uprooting and drying out by hand or farm machinery.

Soil and Water Conservation Sloping Lands with the VS

As a living porous barrier, Vetiver hedge slows and spreads runoff water and traps sediment. As the flow is slowed down, its erosive power is reduced and at the same time allows more time for water to infiltrate to the soil, and the hedge traps any eroded materials (Dabney, 2000). Therefore an effective hedge will reduce soil erosion, conserve soil moisture and trap sediment on site. Additionally these hedges can also act as very effective diversion structures spreading and diverting runoff water to stable areas or proper drains for safe disposal.

Effectiveness of Vetiver Hedges in Soil and Water Conservation and Crop Yield (Nigerian Example)

In Nigeria, Vetiver strips were established on 6% slopes for three growing seasons to assess effects of Vetiver grass on soil and water loss, soil moisture retention and crop yields. Results showed that soil physical and chemical conditions were ameliorated behind the Vetiver strip for a distance of 20m. Crop yields were increased by a range 11 – 26% for cowpea and by about 50% for maize under Vetiver management. Soil loss and runoff water at the end of 20m runoff plots were 70% and 130% higher respectively in non-Vetiver plots than Vetiver plots. Vetiver strips increased soil moisture storage by a range of 1.9% to 50.1% at various soil depths. Eroded soils on non-Vetiver plots were consistently richer in nutrient contents than on Vetiver plots. Nitrogen use efficiency was enhanced by about 40%. This work demonstrates the usefulness of Vetiver grass as a soil and water conservation measure in the Nigerian environment.

Erosion and Sediment Control on Floodplain

When planted in row, Vetiver plants will form a thick hedge and with their stiff stems these hedges can stand up to water flow at least 0.6m deep, forming a living barrier which slows and spreads runoff water. Hydraulic characteristics of Vetiver hedges under deep flow are described in Fig. 2 (Dalton *et al.,* 1996).

Based on the above model, VS has been used successfully for flood erosion control on the floodplains of Queensland, Australia, where strip-cropping practice is used. This practice relies on the stubble of the previous crop for erosion control of fallow land and young crops.

On an experimental site of over 100 ha, Vetiver hedges that were established at 90m intervals to provide a permanent protection against flood water. Results over the last several years, (including several major floods) have shown that VS has been very successful in reducing flow velocity and limiting soil movement, with very little erosion in fallow strips and the young crop was fully protected (Dalton *et al.,* 1996 and Dalton, 1997). The incorporation of Vetiver hedges as an alternative to strip cropping on floodplains has resulted in more flexibility, more easily managed land and more effective spreading of flood flows in dry years particularly with low stubble producing crops such as cotton and sunflower. An added major benefit is that the area cropped at any one time could be increased by up to 30% (Dalton, 1997).

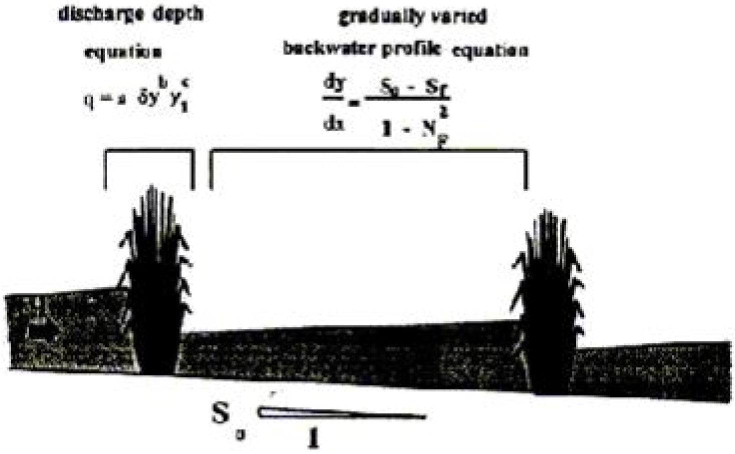

Fig. 2 Hydraulic model of flooding through Vetiver hedges.

where: q = discharge per unit width y = depth of flow y1 = depth upstream
So = land slope Sf = energy slope *N*F = the Froude number

Stream, Irrigation Channel And Levee Banks Stabilisation

Vetiver is highly tolerant to water logging condition; this in combination with its extensive root system, Vetiver provides a highly effective means of stream and levee bank, and irrigation channel stabilisation in Australia and South Africa (Truong , 1999c). Planting on the outside of a dam wall, Vetiver stabilises the steep batter; planting inside the wall protects it from wave erosion. (Troung and Loch, 2004).

OFFSITE POLLUTION CONTROL

De-eutrophication of polluted water

Algal growth in rivers and dams are major concerns around the world, as soluble N and particularly P are usually considered to be key elements for water eutrophication, which normally leads to blue green algal growth in inland waterways and lakes. The removal of these elements by vegetation is a most cost effective and environmental friendly method of controlling algal growth (Troung, 2000).

Chinese researchers have shown that:

• Vetiver has a very high capacity to reduce soluble P, up to 99% after 3 weeks, and 74% of soluble N after 5 weeks (Xia *et al*., 2000; Zheng *et al.*, 2000).

• Vetiver could remove dissolved nutrients and reduced algal growth within two days under experimental conditions (Zheng *et al*., 2000).

Trapping and Decontaminating Agrochemicals and Nutrients

Sediment and runoff analyses associated with the monitoring of the quality of water in tropical Queensland have indicated that, in general, greater than 95% of the nitrogen and phosphorus lost in the runoff are associated with the particulate fraction. Therefore the key in controlling off-site pollution by nutrients and agrochemicals is to control sediment movement. If the sediment could be effectively trapped at source, the degree of downstream pollution would be greatly reduced. Vetiver hedges have been shown to be a very effective and low cost means *of* retention and decontamination of particle-bound agro-chemicals, especially pesticides and nutrients in runoff water from agricultural lands (Troung, 2000)

- In Thailand Vetiver hedges captured and decontaminated pesticides such as carbofuran, monocrotophos and anachlor used in cabbage crops, preventing them from contaminating and accumulating in the soils and crops (Pithong *et al*., 1996, Suchada, 1996).
- On sugarcane farms, Vetiver hedges were highly effective in trapping particulate nutrients such as P and Ca. As expected, the hedges had little effect on soluble forms of nutrients

such as N and K. The effectiveness of Vetiver hedges varied with soil surface treatment and fertiliser placement, being most effective when fertilisers were applied on the soil surface (Troung *et al.,* 2000).

- On cotton farms, when Vetiver was planted as filter strips across drainage lines, soil samples collected at various distances upstream and downstream from the Vetiver hedges, showed that during its first year of growth, for pesticides the Vetiver hedges trapped 86% of total endosulfan in the sediment of runoff water and 67% of chlorpyrifos. For herbicides, during its second year the Vetiver hedge trapped 48% of diuron. For nutrients, similar to the results obtained in canelands, a significant amount of nutrients were trapped by the Vetiver hedges (Troung *et al.,* 2000).
- The high concentration of endosulfan in the trapped sediment resulted in higher endosulfan content in Vetiver tops. While the Vetiver shoot of the first hedge contained on average 0.43 mgkg-1 endosulfan, the shoots of the next hedge down slope only have 0.03 mgkg-1. That is a 14 times reduction (Troung *et al.,* 2000)

Weed and Fire Barrier and Windbreak

When fully developed Vetiver forms a very thick barrier, which can stop stoloniferous or creeping grass such as Bermuda grass spreading. The thick growth of the Vetiver hedges also provides excellent windbreak for young tree and vegetable crops (Troung and Loch, 2004).
Even in a very dry state Vetiver top does not burn readily and remains green during summer so Vetiver is being used in South Africa as a fire barrier protecting forest plantation from creeping grass fire. (Troung and Loch, 2004)

Imperatives For Nigeria

Research that further defines and expands our knowledge of the Vetiver System in relation to our local environment. Although there has been some quite good researches carried out at Ibadan in the 1990s that supports the use of Vetiver for soil and water conservation, it appears to have had little impact outside of the campus.

Practical programs that puts Vetiver systems on the ground for usage in floodplains, slope stabilization, off-site pollution control and disaster mitigation. For example in the Congo there has been excellent work that focuses on slope stabilization and ravine rehabilitation - this was undertaken using technical data and Vetiver applications that have been created worldwide. Alain tweaked the generic applications to fit the needs of the specific sites. Large and practical interventions are required in Nigeria that is supported by government development policies and appropriate support and actions to NGOs and the private sector.

CONCLUSION

Just as Vetiver grass have been successfully established in northern California and thrives in Nigeria with global experience to prove its adaptive worth, VS represents a reliable, sustainable, reproducible and simple-to-mange soil and water conservation practice. It can provide for Nigeria, multiple returns on agricultural productivity and environmental protection

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