Feature article

MULTIPLE BENEFITS OF THE VETIVER SYSTEM AND ITS ENVIRONMENTAL APPLICATION IN ETHIOPIA

HABTEMARIAM ABATE[1] AND BELAY SIMANE[2]

1. Sustainable Land Use Forum (SLUF), E-mail: habtea2001@gmail.com, slufethiopia@gmail.com
2. Environment and Agricultural Development, Institute for Environment, Water and Development Studies, Addis Ababa University. Email: simaneb@yahoo.com

ABSTRACT

Vetiver grass is a C4 perennial grass that fits well in ecosystem service model contributing to local and national economies for its multifarious environmental applications, and offers sustainable opportunities for carbon sequestration. Vetiver grass has been used for degraded land reclamation, erosion control and slope stabilization for centuries and its popularity has increased remarkably in the last decades in many parts of the world including Ethiopia. This is due to its unique morphological, physiological and ecological characteristics including its massive root system, tolerance to highly adverse growing conditions and tolerance to high levels of toxicities. Vetiver is a fast growing grass, and possesses some unique features of both grasses and trees by having profusely grown, deep penetrating root system that can offer both erosion prevention and control of shallow movement of surface earth mass. It is also cost-effective and environment-friendly. Vetiver System (VS) involves the correct application of this unique grass in erosion and sediment control, land reclamation, rehabilitation and stabilization etc. Although Vetiver grass was first introduced to Ethiopia by Jimma Research Center in 1970, it was not widely disseminated until Sustainable Land Use Forum (SLUF) and its partners demonstrated it in a large scale in Ethiopia. Vetiver grass is a very simple, practical, inexpensive, low maintenance and very effective means of soil and water conservation, sediment control, land stabilizations and rehabilitation, and phyto-remediation in the Ethiopian perspective. The Ethiopian Vetiver Network (ETVN), established in 2009 works to integrate the Vetiver System into sustainable land management practice, create awareness on the Vetiver System Application (VSAs) to policy makers, development actors and the public at large, and provide training to development agents and farmers and to promote and scale up/out of the use of the Vetiver System for SWC, environmental rehabilitation, stabilization and protection of infrastructures, and mitigation of climate change in Ethiopia. Currently the grass has become widely known throughout the country with numerous successful applications for road cut-slope stability enhancement, erosion/flood control of embankments, dykes, riverbanks, sand dune fixation as well as waste and leachate control *etc*. Even though, the application of Vetiver System for erosion control and slope stabilization have been implemented for the last 30 years in Ethiopia, there is a lot of opportunity to refine existing applications in Ethiopia through integrated research and development efforts by involving all stakeholders at all levels.

Key Words: climate change, land reclamation, slope stabilization, soil and water conservation, Vetiver System,

Running title: Vetiver system application in Ethiopia

INTRODUCTION

The use of vegetation as a bio-engineering tool for land reclamation, erosion control and slope stabilization have been implemented for centuries and its popularity has increased remarkably in the last decades (Truong, 2002). This is partly due to the fact that more knowledge and information on vegetation are now available for application in engineering designs, but also partly due to the cost-effectiveness and environment-friendliness of this “soft”, bioengineering approach.

Vetiver grass (*Vetiveria zizanioides* L. Nash) is a tall perennial grass belonging to the poacea family (Photo 1). South India is considered as Vetiver center of origin from where it is said to have spread. It is distributed mainly in Asia, Africa, and America and grows luxuriantly in well drained sandy loam soil and in areas with annual rainfall of 300 – 2000 mm and temperatures ranging from 15^0C to 55^0C. The grass has short rhizomes and massive, finely structured root system that grows very quickly in some applications. Its root depth reaches 3-4 m in the first year. The deep root system makes the Vetiver plant extremely drought tolerant and very difficult to dislodge when exposed to a strong water flow. Similarly, the Vetiver plant is also highly resistant to pest, disease and fire (SLUF, 2009).

Although Vetiver grass has been used first by Indian farmers for soil and water conservation more than 200 years ago, its real impact on land stabilization/reclamation, soil erosion and sediment control only started in the late 1980’s following its promotion by the World Bank (Greenfield, 2002). While it still plays a vital role in agriculture, the unique morphological, physiological and ecological characteristics of the grass including its tolerance to highly adverse growing conditions and tolerance to high levels of toxicities provide an unique bio-engineering tool for other, non-agricultural applications such as land stabilization/reclamation, soil erosion and sediment control.

Photo 1: Erect and stiff stems form a dense hedge when planted close together. The roots could penetrate though the hard pan soil.

Current vetiver grass applications include soil and water conservation in agricultural lands, steep slope stabilization, mine, contaminated and saline lands rehabilitation (Truong, 1999) and recently wastewater treatment (Truong and Hart, 2001). This is due to its unique morphological, physiological and ecological characteristics that permit it to adapt to a wide range of climatic and soil conditions (Truong, 2002). Vetiver grass can establish itself in hostile conditions and creates micro-climates that permit a variety of other indigenous plants to prosper. As a result, the system is now increasingly being used for these purposes in over 120 countries.

Vetiver grass is a very simple, practical, inexpensive, low maintenance and very effective means of soil and water conservation, sediment control, land stabilizations and rehabilitation, and phyto-remediation. Being vegetative it is also environmental friendly. When planted in single rows Vetiver plants will form a hedge which is very effective in slowing and spreading runoff water, reducing soil erosion, conserving soil moisture and trapping sediment and farm chemicals on site. Although any hedges can do that, Vetiver grass, due to its extraordinary and unique morphological and physiological characteristics mentioned lower, can do it better than all other systems tested. In addition, the extremely deep and massively thick root system of Vetiver binds the soil and at the same time makes it very difficult for it to be dislodged under high velocity water flows. This very deep and fast growing root system also makes Vetiver very drought tolerant and highly suitable for steep slope stabilization.

A review conducted for the World Bank comparing the effectiveness and practicality of different soil and water conservation systems found that constructed measures are site specific and require detailed and accurate engineering and design. They also require regular maintenance. Most of the evidence also suggests that constructed works reduce soil losses, but do not reduce runoff significantly and in some cases have a negative impact on soil moisture (Greenfield, 1989). On the other hand, the vegetative conservation system, when planted on the contour, forms a protective barrier across the slope, which slows the runoff water causing sediment to be deposited. Since the barriers only filter the runoff and do not convey it, water seeps through the hedge, reaching the bottom of the slope at lower velocity without causing any erosion and without being concentrated in any particular area (*ibid*). This is in sharp contrast with the contour terrace/waterway system in which runoff water is collected by the terraces and diverted as quickly as possible from the field to reduce its erosive potential. All runoff water is therefore collected and concentrated in the waterways where most erosion occurs in agricultural lands, particularly on sloping lands, and this water is lost from the field. With the flow-through system, not only is this water conserved but also no land is wasted on the waterways (Fig.1).

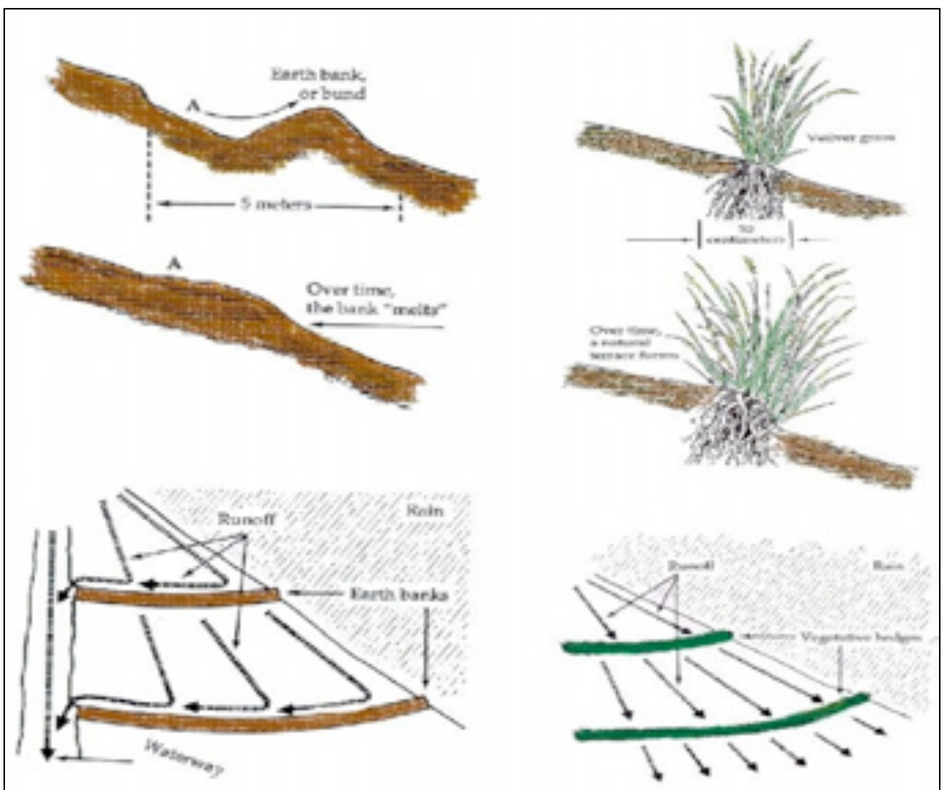

Figure 1: Comparison between conventional terrace/contour system and VS in soil and water conservation (Greenfield, 1989)

This paper, attempts to discuss the special morphological, physiological and ecological characteristics of Vetiver grass, and describes the application and effectiveness of Vetiver System in the Ethiopian context.

SPECIAL FEATURES OF VETIVER GRASS

Vetiver grass is a densely tufted, perennial clump grass with stiff leaf bases which overlap and has the following morphological physiological and ecological features (Truong, 2004):

Morphological features

- Vetiver grass does not have stolons or rhizomes. Its massive finely structured root system 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 water currents.
- Stiff and erect stems that can stand up to relatively deep water flows (Photo 1).
- Highly resistance to pests, diseases and fire (Photo 2).
- A dense hedge is formed when planted close together, acting as a very effective sediment filter and water spreader.
- New shoots develop from the underground crown making Vetiver resistant to fire, frosts, traffic and heavy grazing pressure.
- 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.

Physiological features

- Tolerance to extreme climatic variation such as prolonged drought, flood, submergence and extreme temperature from -14ºC to +55ºC.
- Ability to re-grow very quickly after being affected by drought, frosts, salinity and adverse conditions after the weather improves or soil ameliorants added.
- Tolerance to wide range of soil pH ranging from 3.3 to 12.5 without soil amendment.
- High level of tolerance to herbicides and pesticides.
- Highly efficient in absorbing dissolved nutrients such as N and P and heavy metals in polluted water.
- Highly tolerant to grow in soils with acidity, alkalinity, salinity, sodicity and magnesium. (Photo 3 and 4)
- Highly tolerant to Al, Mn and heavy metals such as As, Cd, Cr, Ni, Pb, Hg, Se and Zn in the soils.

Ecological features

- Although Vetiver is very tolerant to some extreme soil and climatic conditions mentioned above, as typical tropical grass, it is intolerant to shading. Therefore, Vetiver grows best in an open and weed free environment; weed control may be needed during establishment phase.
- On erodible or unstable ground Vetiver first reduces erosion, stabilizes the erodible ground (particularly steep slopes), then because of nutrient and moisture conservation, improves its micro-environment so that other plants can establish later. Because of these characteristics Vetiver can be considered as a nurse plant on disturbed lands.

- Most varieties of Vetiver are naturally sterile hybrids and do not set seed, and because Vetiver does not produce stolons, there is no danger of the grass spreading from where it is planted.

Photo 2: left: Vetiver grass surviving forest fire; right: two months after the fire (Australia).

Photo 3: Vetiver on coastal sand dunes in Quang Bình (left), and saline soil in Gò Công Province (right) (Vietnam).

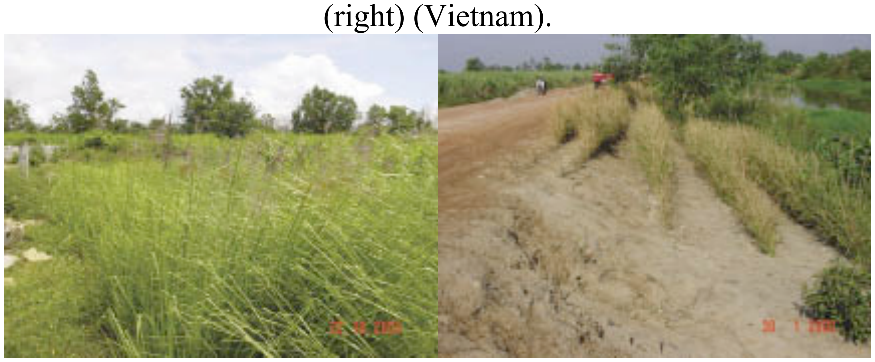

Photo 4: Vetiver on extreme acid sulfate soil in Tân An (left), and alkaline and sodic soil in Ninh Thuận (right) (Vietnam).

APPLICATION AND EFFECTIVENESS OF VETIVER SYSTEM

In addition to its use for soil and water conservation and restoration of degraded ecosystems like wet lands, river banks, road sides and polluted water treatment, the Vetiver System is also currently recognized as one of the best strategies for mitigation and adaptation to impacts of climate change since it sequesters carbon in the soil (Lavania and Seshu, 2009). It also generates income for local communities and thereby enhances ecosystems and social resilience. It has been also widely known for its effectiveness in the following applications (Greenfield, 2002; Truong and Baker, 1998; Truong, 1999).

1. Soil and Water Conservation

Vetiver grass, due to its unique morphological and physiological characteristics, has been widely known for its effectiveness in erosion and sediment control (Greenfield, 2002). The use of vegetation as a bio-engineering tool for land reclamation, erosion control and slope stabilization have been implemented for centuries and its popularity has increased remarkably in the last decades. Vetiver's soil binding root system and its ability to form dense hedgerows is unmatched by any other plant used for on-farm erosion control. In addition to reducing surface erosion on sloping land, vetiver's massive root system also contributes to slope stability. Its stiff stems form a form a dense hedge that reduces water velocity, allows more time for water to infiltrate the soil, and, where necessary, divert surplus runoff water (Photo 1).

Vetiver is very effective when planted closely in rows on the contour slopes. Contour lines of vetiver can stabilize natural slopes, cut slopes and filled embankments. Its deep, rigorous root system helps stabilize the slopes structurally while its shoots disperse surface run-off, reduce erosion, and trap sediments to facilitate the growth of native species (Photo 5). In Ethiopia, it is widely used for controlling soil erosion, preserving soil moisture and rehabilitating deteriorated land and infrastructure. According to Afework Hailu (2009), coffee based cropping system in Wichi area of Illubabor showed that Vetiver hedgerow was effective in reducing the soil loss during the third cropping season (Table 1). The use of Vetiver grass together with physical measures was also found very important to control the gully side and heads.

Photo 5. Farm land protected with Vetiver terrace Metu- Ethiopia

Table 1. Effect of Vetiver grass hedgerow on runoff control (Afework Hailu, 2009)

Years	Annual rainfall (mm)	Runoff (mm)		
		Bare land	Vetiver on bare land	Vetiver with coffee
2001	1595.7	226.2	160.3	167.1
2002	1450.9	182.8	89.8	65.3
2003	1348.0	139.4	36.8	17.3

In India, on a cropland with 1.7% slope, Vetiver contour hedges reduced runoff (as percentage of rainfall) from 23.3% (control) to 15.5%, and soil loss from 14.4 t/ha to 3.9 t/ha. At the same time, sorghum yield increased from 2.52 t/ha to 2.88 t/ha over a four year period. The yield increase was attributed to mainly in situ soil and water conservation over the entire toposequence under the Vetiver hedge system (Truong, 1993). Under small plot conditions at the

International Crops Research Institute for the Semi-Arid Tropics, Vetiver hedges effectively controlled runoff and soil loss more than lemon grass or stone bunds. Runoff from the Vetiver plots was only 44% and 16% of that of the control plots on 2.8% and 0.6% slope lands respectively. Relative to control plots, average reductions of 69% in runoff and 76% in soil loss were recorded from Vetiver plots (Rao *et al.*, 1992).

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 (Babola *et al*., 2003).

Similar results were also reported on a range of soil types, land slopes and crops in Venezuela and Indonesia In Natal, South Africa, Vetiver hedges have increasingly replaced contour banks and waterways on steep cane lands, where farmers have found that the Vetiver system is the most effective and low cost form of soil and water conservation in the long term (Grimshaw, 1993). Results of a cost benefit analysis conducted on the Maheswaran watershed in India (Rao, 1993) where both engineering structures and vegetative barriers with Vetiver grass were used, showed that Vetiver systems are more profitable even during the initial stages due to their efficiency and low cost.

In Queensland, Australia Vetiver grass Research and Development from 1977 to 1993 have confirmed overseas findings, particularly its effectiveness in soil and water conservation, gully stabilization, degraded land rehabilitation and trapping sediment in waterways and depressions (Table 2).

Table 2: Effects of the Vetiver System on soil loss and runoff in agricultural lands (Rodriguez 1993)

	Soil loss (t/ha)			**Runoff (% of rainfall)**		
Countries	**Control**	**Conventional**	**VS**	**Control**	**Conventional**	**VS**
Thailand	3.9	7.3	2.5	1.2	1.4	0.8
Venezuela	95.0	88.7	20.2	64.1	50.0	21.9
Venezuela (15% slope)	16.8	12.0	1.1	88	76	72
Venezuela (26% slope)	35.5	16.1	4.9			
Vietnam	27.1	5.7	0.8			
Bangladesh		42	6-11			
		25	2			
India		14.4	3.9		23.3	15.5

2. Slope stabilization

Vetiver grass' morphological, physiological and ecological characteristics including its tolerance to highly adverse growing conditions provide a unique bio-engineering tool for land stabilization, soil erosion and sediment control. The main reasons for slope instability are surface erosion and structural weakness of the slope. While surface erosion often leads to rill and gully erosion, structural weakness will cause mass movement or landslip (Truong *et al*., 2003).

Vetiver is very effective when planted closely in rows on the contour of slopes. Contour lines of vetiver can stabilize natural slopes, cut slopes and filled embankments. Its deep, rigorous root system helps stabilize the slopes structurally while its shoot disperse surface run-off, reduce erosion, and trap sediment to facilitate the growth of native species (Troung, et al., 2008)

Edges of ponds, dams and reservoirs, road shoulders, gullies, hills, roadsides etc. are areas, where cultivation of vetiver should be carried out for conserving the environment and the infrastructures themselves. Vetiver is termed as “soil nail” or “living nail” for its effective conservation role of road and water infrastructures.

Soil should be fertilized to enhance growth performance and clumps should be trimmed to allow side growth and tillering. The thicker the clump, the more effective it will be in trapping silts from runoff and in preventing erosion. Another pattern is to plant Vetiver horizontally across the gully to trap silts which eventually fill up the gully. On critically deteriorated land, it is vital to shape Vetiver clumps and strengthen them by planting more rows and accelerating growth performance using fertilizer, which thus effectively retards heavy runoff.

Presently Vetiver grass has been widely used for erosion and sediment control on steep slopes around the world: including Africa, Asia, central and south America, southern Europe and Australia where it has been used successfully to stabilize steep batters of road and railway in north, central and south east Queensland. In China, the Vetiver System has been used for erosion and sediment control on more than 150,000 km of railway, highway and road batters in the last 5 years.

Research conducted by Hengchaovanich and Nilaweera (1996) showed that the tensile strength of Vetiver roots increases with the reduction in root diameter. The tensile strength of Vetiver roots varies between 40-180 Mpa for the range of root diameter between 0.2-2.2 mm. The mean design tensile strength is about 75 Mpa (equivalent to approximately one sixth of mild steel) at 0.7-0.8 mm root diameter, which is the most common size for Vetiver roots. This indicates that Vetiver roots are as strong as, or even stronger than that of many hardwood species, which have been proven positive for root reinforcement in steep slopes. In a soil block shear test, the root penetration of a two year old Vetiver hedge with 15cm plant spacing can increase the shear strength of soil in adjacent 50 cm wide strip by 90% at 0.25 m depth. Vetiver can grow vertically on slopes steeper than 150%. It is faster growing and imparts more reinforcement, making it a better candidate for slope stabilization than other plant.

3 River bank stabilization and dam protection

Using vetiver grass to stabilize river banks and canal walls is another recommended practice. The combination of the deep root system and thick growth of the vetiver hedges will protect the banks of river and stream under flood conditions. Its deep roots prevent it from being washed away while its thick top growth reduces flow velocity and its erosive power. In addition properly laid out hedges can be designed to direct water flow to appropriate areas. Field trials using hydraulic characteristics determined by the above-mentioned tests (Dalton et al, 1996b) showed that vetiver hedges were successful in reducing flood velocity and limiting soil movement, resulting in very little erosion in fallow strips and a young sorghum crop was completely protected from flood damage.

A similar approach can be taken to protect dams. Small dams are silting up at an alarming rate in Ethiopia. If vetiver grass is planted around the sides of the dam, the silt carried by runoff from the surrounding hills will be trapped before it reaches the dam.

4. Mulching and enriching the organic contents of degraded lands

The purpose of Vetiver cultivation on flat land is to use the leaves for mulching so as to preserve soil moisture and conserve rainwater in the soil (Photo 7). Another benefit from mulching is to restore deteriorated land by enriching the organic contents and allowing the translocation of minerals from the lower layers to the upper layers of the soil. According to (Tesfaye Kumsa and Gadissa Gobena, 2009), an abandoned State Farm is transformed into a productive improved maize seed farm producing up to 12 tons per hectare in Anno Agro Industry PLC farm at Gobusyo Wereda, East Wellega. Vetiver is also cultivated on flat land for propagation purposes (Photo 8). For this topographical condition, Vetiver grass can be cultivated in any single or integrated patterns such as in rows, semi-circle, circle, etc.

Photo 7: Multch on pineapple (JRC)

Photo 8: vetiver bank (E.Gojjam)

5. Flood control

On the flood plains of the Darling Downs and on the northwestern slopes of New South Wales in Australia, strip-cropping is used to mitigate floodwater damage to crops and to control soil erosion on low gradient lands subject to deep overland flooding (Dalton *et al.* 1996a). Crops are planted on the contour in a sequence of crop, stubble and fallow strips of uniform width arranged perpendicular to the flood flow direction with the aim of spreading the flood waters laterally, thus reducing the depth, velocity and consequently the erosivity of flow. Strip cropping uses a similar "flow-through" system as that of Vetiver grass hedges. Strip cropping requires a strict sequence of crop rotation but at times provides little protection from erosion during drought or when low stubble producing crops such as sunflower or cotton are grown in alternate strips.

Results over the last several years, (including several major flood events) have shown that the Vetiver System is very successful in reducing flood velocity and limiting soil movement, with very little erosion in fallow strips (Truong *et al*., 1996; Dalton *et al.* 1996a; 1996b).The results of the trials demonstrated that the Vetiver System are considered as an alternative to strip cropping practice on the flood plains of Australia.

6. Mitigation and adaptation to climate change

Sequestration of atmospheric carbon into subsoil horizons is one of the strategic measures to be taken along this line. Fast growing grasses with penetrating deep root system would facilitate long-term locking of atmospheric carbon below plough layer with reduced chances of being recycled to atmosphere and recuperate soil carbon sink. Vetiver is an ideal global candidate with a holding potential of 1 kg atmospheric carbon, sequestered annually deep into the soil pool from one square meters surface area (Lavania and Seshu, 2009).

Income and livelihood diversification is one among the several strategies available to enhance social resilience and adapt to climate change. Vetiver grass has the following socioeconomic benefits:

- On top of its ecological services, Vetiver is used as fodder and fiber and generates income for local communities. Its leaves and roots can be used for other purposes especially its leaves, which usually have to be cut to keep the Vetiver rows in order and can be used for roofing as well as making handicraft products (basketry and kitchen utensils, home decoration items, accessories, office supplies) to gain extra income (Photo 9) .

- The aromatic Vetiver roots are used for making perfumes, medicine (aromatherapy) and fans, cloth hangers or are mixed with other dried flowers and leaves to make different other materials.
- Vetiver can also be used for pest control such as stalk borer in maize and sorghum, nematodes, etc. In this regard Vetiver integrates well with conservation agriculture practices. Vetiver is also a good ornamental grass.


Photo 9. Handicraft products ma

7. Vetiver as forage

The use of Vetiver as dual-purpose forage by smallholder farmers in the rainfed upland areas of the Philippines has been widely reported (Neguyen et al, 2008). It was also reported to be edible herbage of high quality for cattle and goats particularly in the growing stage. Vetiver grass may also be a promising feed resource because of its various advantages including high quality, fast growth rate and easy adaptation to the environment and can therefore bear repetitive mowing without occupying farming land. Data on chemical composition of the feeds are presented in

Table 3. There was a wide range in nutritive values from foliage to grass and legume. Generally, tree foliages had higher crude protein content and much less fiber than grass.

Table 3. Chemical composition of Vetiver compared with other feed species in Vietnam (Neguyen et al, 2008).

Species	DM (g/kg)	**g/kg DM**			
		Ash	**CP**	**NDF**	**ADF**
Vetiver	239	90	113	711	330
Brachiaria multica	167	101	114	643	331
Sesbania grandiflora	194	85	236	304	210
Leucaena leucocephala	262	67	253	422	227
Trichanthera gigantea	147	234	208	420	315

VETIVER SYSTEM IN ETHIOPIA

Vetiver grass was first introduced to Ethiopia by Jimma Research Center (JRC) of the Ethiopian Institute of Agricultural Research (EIAR) in 1970 from India (Alemu Mekonen, 2000). The purpose of its introduction was mainly to demarcate the different coffee estates and to control the expansion of a noxious grass called *Cynodon dactylon*. In 1984 Vetiver was distributed for the first time out of the JRC to nearby coffee state farms and a development site of Menschen für Menschen (MfM), a German-based NGO, to utilize the plant as mulch and for soil and water conservation purposes. The first nursery was established in the early 1990 by MfM, in south western part of the country. In subsequent years, it was introduced to other areas covering the different weredas of Illuababora, Debre Zeit, and Holetta Research Center mainly for soil erosion control. In 1990s, it was distributed throughout the country. Ultimately, the grass is now being used by farmers, rural road experts, urban dwellers small-scale cottage industries, and wetlands development projects for various purposes. It was probably after the *Vetiver Newsletter* started in 1989 and the first national workshop held in 1991 that most people became aware of the wonder grass as the cheapest means of erosion control in croplands (Alemu Mekonen, 2000).

The grass has been used intensively for soil and water conservation and stabilization of steep slopes (Photo 5). The effects of Vetiver hedges in controlling flood water and soil erosion were studied at Jima Research Center (Tesfu Kebede and Tesfaye Yakob, 2009). The findings were successful in reducing flood velocity and limiting soil movement, resulting in very little erosion in the third year.

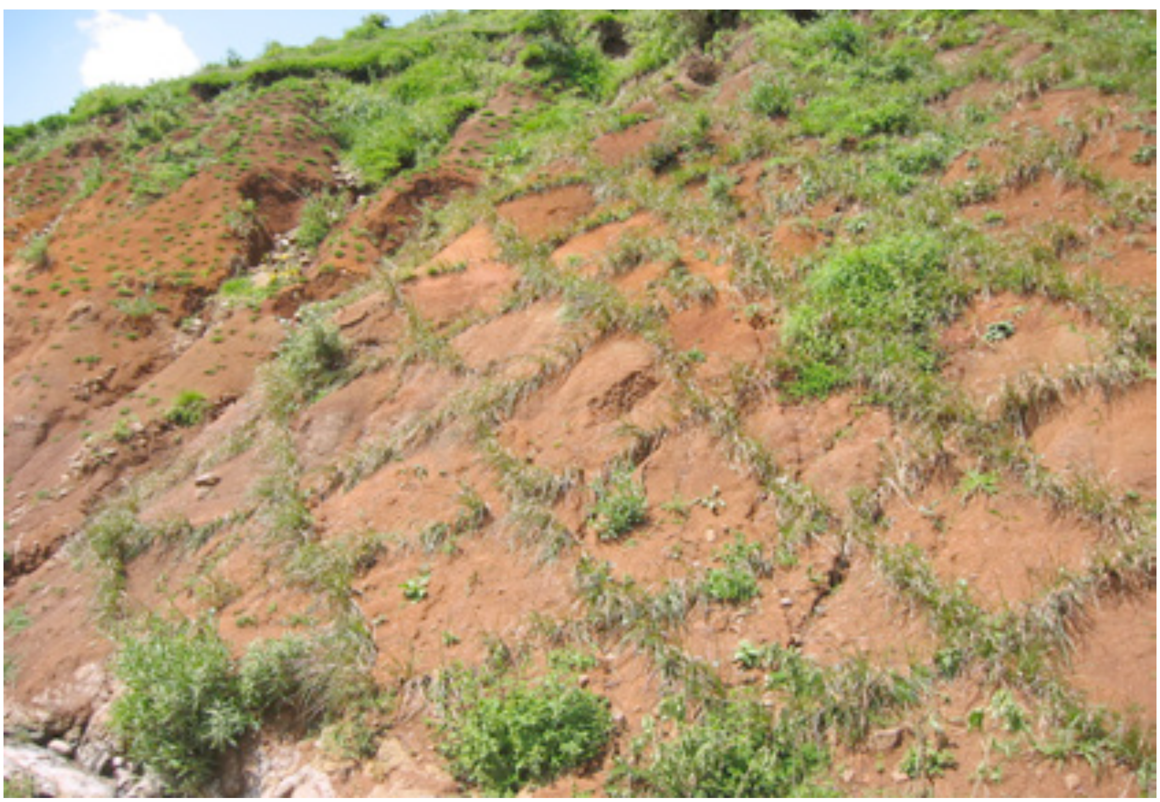

Photo 5. Applications of Vetiver grass for landscape stabilization (GTZ-IFSP/ South Gonder, 2005)

A study under coffee-based cropping system showed that Vetiver hedgerow is effective in reducing the soil loss during the third cropping season. It was also noted that the use of Vetiver grass together with physical measures is very important to control the gully side and heads from further erosion (SLUF, 2009). SLUF and its partners have demonstrated and applied the Vetiver system on a large scale in Ethiopia and recommended it as best practice for soil and water conservation and infrastructure protection (Photo 6 and 7). It has also documented that Vetiver grass is a very simple, practical, inexpensive, low maintenance and very effective means of soil and water conservation, sediment control, land stabilizations and rehabilitation, and phyto-remediation (SLUF, 2010). Currently the grass has become widely known throughout the country with numerous successful applications for road cut-slope stability enhancement, erosion/flood control of embankments, dykes, riverbanks, sand dune fixation as well as waste and leachate control *etc*.

Photo 6: Vetiver grass used for infrastructure protection (Afar region)

Photo 7: Vetiver application in gully treatment and soil and water conservation (Amhara region)

Recognizing that integrating the Vetiver grass into sustainable land management practice, creating awareness on the Vetiver System Applications (VSAs) to policy makers, development actors and the public at large, and training of professionals, development agents and farmers would have enhanced environmental protection and food security in Ethiopia, the Ethiopian Vetiver Network (ETVN), housed in SLUF was established on July 31, 2009 by the participants of the national workshop on "The Vetiver System for Soil and Water Conservation, Environmental Protection and Land Rehabilitation in Ethiopia", which was conducted from 16-18 March 2009 in Addis Ababa (SLUF, 2009).

ETVN is a multi stakeholder network constituting organizations from the government sector such as the Ministry of Agriculture, Jimma Research Center, Coffee Plantation and Development Enterprise, Ethiopian Road Authority; NGOs such as SLUF, GTZ, Consortium for Integration of Population, Health and Environment (CIPHE), Ethiopian Wetlands and Natural Resources Association (EWNRA); international organizations such as WFP and UNDP GEP-SGP; private sector like Anno Agro-industry PLC and a green award winner small farmer and a private consultant. The objectives of the network are:

- Knowledge management, documentation and networking
- Leadership, advocacy, lobby, fund soliciting and monitoring and evaluation; and
- Training, research and extension.

To achieve the stated objectives, the network has organized itself into three teams and has achieved several accomplishments especially in the area of advocacy, lobby, documentation and networking. It has also developed seven joint development projects (3 watershed *viz* Gilgel Gibe hydropower I, Tekeze hydropower, and Tendaho sugar estate and 4 factories *viz.* Harar Beer, Almeda, Addis winery, and Sebeta) (Habtemariam Abate, 2010). A memorandum of understanding for implementation was also signed between SLUF and EPA.

CONCLUSIONS AND RECOMMENDATIONS

Vetiver grass is a C4 perennial grass that could be grown all across the globe from tropical to Mediterranean climate. The grass fits well in ecosystem service model contributing to regional and global economies for its multifarious environmental applications, and offers sustainable opportunities for carbon sequestration. Vetiver grass, due to its extraordinary and unique morphological and physiological characteristics, is a very simple, practical, inexpensive, low maintenance and very effective means of soil and water conservation, sediment control, land stabilizations and rehabilitation, and phyto-remediation. When planted in single rows Vetiver plants will form a hedge which is very effective in slowing and spreading runoff water, reducing soil erosion, conserving soil moisture and trapping sediment and farm chemicals on site. The extremely deep and massively thick root system of Vetiver binds the soil and at the same time makes it very difficult for it to be dislodged under high velocity water flows. This very deep and fast growing root system also makes Vetiver very drought tolerant and highly suitable for steep slope stabilization.

The Vetiver System would be the best stand alone technology in the Ethiopian context at low cost and without high demands on professional and financial resources. Based on the past 20 years of experience in Ethiopia and other countries worldwide, there are enormous opportunities to up-scaling the VS that would contribute to the country's efforts in poverty reduction and sustaining the environment.

- The morphological, physiological and ecological characteristics Vetiver grass, including its tolerance to highly adverse growing conditions provide a unique bio-engineering tool for land stabilization, soil erosion and sediment control. The use of vegetation as a bio-engineering tool for land reclamation, erosion control and slope stabilization have been implemented for centuries and its popularity has increased remarkably in the last decades.

- Vetiver System is widely used for mulching and enriching the organic contents of degraded lands on flat land. It preserves soil moisture and conserves rainwater in the soil. Another benefit from mulching is to restore deteriorated land by enriching the organic contents and allowing the translocation of minerals in the lower layers to the upper layers of the soil.
- Vetiver System has socioeconomic benefits to enhance social resilience and adapt to climate change. Vetiver is used as fodder, fiber, roofing, handcrafting and generates income for local communities.
- Vetiver System is very successful in reducing flood velocity and limiting soil movement, with very little erosion in fallow strips.

Even though, the application of vegetation for erosion control and slope stabilization have been implemented for the last 30 years in Ethiopia and its popularity has increased remarkably after the establishment of the Ethiopian Vetiver Network in recent years, there is a lot of opportunity to refine existing applications in Ethiopia. The following development and research activities on Vetiver grass are recommended to refine the already available technologies and other potential use of the Vetiver grass that may help to enhance its utilization and integration in various food security and environmental management systems:

- document and disseminate the already available technologies in SWC activities and other potential use of the Vetiver System in local languages;

- study establishment and management practices of Vetiver System under various ecosystems and farming systems;
- conduct applied and basic research to assess and document its morphological, physiological and ecological characteristics in the Ethiopian context;
- study the environmental, economic and social aspects of Vetiver applications under varied ecosystem and farming systems;.
- promote leadership, advocacy and lobby, fund soliciting and monitoring and Evaluation;
- provide tailor-made trainings and enhanced extension services to the development practitioners and farmers; and
- incorporate vetiver into education carricula of schools and higher learning institutes

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