
Vetiver Grass: A Tool for Sustainable Agriculture

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Abstract

Vetiver grass is a densely tufted bunch grass which can be easily established in both tropics and temperate regions of the world. It plays a vital role in watershed protection by slowing down and spreading runoff harmlessly on the farmland, recharging ground water, reducing siltation of drainage systems and water bodies, reducing agro-chemicals loading into water bodies and for rehabilitation of degraded soils. Vetiver grass could tolerate extremely high levels of heavy metals. It could be used as biological pest control. The use of vetiver grass has been regarded as a low-cost technology for soil and water conservation; on- and off-farm land and water sources stabilization and remediation of polluted soils; and enhancement of water quality for irrigation purposes when compared with other soil conservation technologies. It could be a dynamic tool for mitigating environmental and agricultural problems, thereby enhancing crop yield and supporting all-year round agricultural cultivation. Recently, vetiver grass has been used to raise animals of different kinds. Thus, this chapter in the book explores several applications of vetiver grass, its impacts and resultant benefits as a technology that could enhance sustainable agricultural development.

Keywords: soil conservation, bioremediation, soil amendment, crop productivity, soil stabilization

1. Introduction

Soil is an integral part of the environment that is involved in many ecosystem services. However, decline in the actual and/or potential productivity of soils due to poor land management practices has become a major challenge to sustainable agriculture and environmental quality [1], thus threatening the food security of many countries of the world. According to Truong [2], some of these poor land management practices often lead to soil erosion and

agro-chemical contamination from agricultural practices, urban wastes and industrial operations, which adversely reduces soil's potential for sustainable food production, consequently affecting plants, animals and human lives.

In Truong [2], soil conservation methods such as contour banks, earthen bunds and concrete structures employed to rehabilitate lands with low soil quality are expensive, short-lived and sometimes impossible to execute. He finally reported that vegetative methods, such as the use of grasses, are an effective erosion and sediment control technology which are practicable and economical for the rehabilitation of lands for agricultural production. Vetiver grass (*Vetiveria zizanioides* L.) has been reported to be effective in erosion control [3] and remediation of contaminated soils [4]. According to Rao [5], due to their efficiency and low-cost, vetiver systems are more profitable than both engineering structures and other vegetative barriers. In Ref. [6], vetiver was reported to be highly tolerant to extreme soil conditions including heavy metal contaminations. In comparison with other grasses for rehabilitation of lands with adverse soil conditions, vetiver grass was reported to be superior to Bermuda grass (*Cynodon dactylon*) which has been recommended as a suitable species for acid mine rehabilitation [7]. Also, in an attempt to revegetate a highly saline land, Truong [8] reported superior performance of vetiver grass over Rhodes (*Chloris guyana*) and saltwater couch (*Paspalum vaginatum*), as it was able to survive and resume growth under very high saline conditions. This is due to its unique morphological and physiological characteristics which enables it to survive where other plants cannot [9].

2. Brief description of vetiver grass

Vetiver grass (*V. zizanioides* L.) is a perennial tufted plant that is native to India (**Figure 1**). It is described as a coarse Asian plant [10]. Although *V. zizanioides* is also commonly found in West Africa, an African counterpart, *V. nigriflora*, has been reported to be far more common [10]. **Table 1** shows some countries where vetiver grass is known to exist. According to Truong [11], vetiver grass possesses a root system that is abundant, complex, extensive and vertical in nature. According to National Research Council [10], the root grows almost straight down with few lateral surface roots, thus not interfering with the growth of other crops which could result in loss of yield. In Hengchaovanich [12], it was explained that the root system of vetiver grass can reach 3–4 m in the first year of planting, while [13] reported that it attains a total length of 7 m after 36 months. The roots are very strong with a mean tensile strength of between 75 and 85 MPa [14]. The leaves are thin and have sharp edges [10], while the shoots can grow up to 2 m. The mature foliage is tough and coarse, which enables it to stay in place for years [10]. They further reported that this attribute is important as an erosion control crop provided it is to work effectively. Its growth occurs from the crown, which rises relative to soil build-up [9]. The crown of the plant occurs slightly below the soil surface and as such no lasting damage can be done on it by grazing or trampling animals [10].

2.1. Vetiver grass technology

Vetiver grass has been reported to be very effective in trapping both fine and coarse sediments in runoff water [10]. These sediments constitute bulk of the fertile layer (topsoils) of



Figure 1. Vetiver (*Vetiveria zizanioides* L.) grass strips at the University of Ibadan, Nigeria.

Africa	America	Asia	Caribbean	Pacific	Others
Algeria	Argentina	Bangladesh	Antigua	American Samoa	France
Angola	Brazil	Burma	Barbados	Cook Islands	Italy
Burundi	Colombia	China	Cuba	Fiji	Spain
Comoro	Costa Rica	India	DR	New Caledonia	USA
CAR	FG	Indonesia	Haiti	New Guinea	USSR
Ethiopia	Guatemala	Japan	Jamaica	Tonga	
Gabon	Guyana	Malaysia	Martinique	Western Samoa	
Ghana	Honduras	Nepal	Puerto Rico		
Kenya	Paraguay	Pakistan	St. Lucia		
Madagascar	Suriname	Philippines	St. Vincent		
Malawi		Singapore	Trinidad		
Mauritius		Sri Lanka	Virgin Islands		
Nigeria		Thailand			
Rwanda					
Reunion					
Seychelles					
Somalia					

Africa	America	Asia	Caribbean	Pacific	Others
South Africa					
Tanzania					
Tunisia					
Uganda					
Zaire					
Zambia					
Zimbabwe					

Note: CAR, Central African Republic; FG, French Guiana; DR, Dominican Republic (source: Ref. [10]).

Table 1. Some countries where vetiver is known to exist.

most agricultural lands, which is critical for crop cultivation. In addition, vetiver grass has been reported to have high tolerance for extreme adverse conditions, including heavy metal toxicity [15], hence making it suitable for the remediation of heavy metal-contaminated soils. This could be due to some of its special attributes which makes it an ideal species for environmental protection and sustainable agriculture. Some of these characteristics include massive, fine-structured root system [16]; high resistance to pests, diseases and fire [17]; high efficiency in absorbing dissolved N, P, Hg, Cd and Pb in polluted water [18]; and good and fast recovery rate after being affected by the previously listed adverse conditions [19].

2.2. Applications of vetiver grass

The application of vetiver grass as a technology for soil and water conservation was first developed in India by the World Bank in the 1980s [2]. Some of the applications of vetiver grass technology, which could sum up to the enhancement of sustainable agricultural development, include its use for soil erosion and sediment control on sloping farmlands and floodplains [20–24]; rehabilitation of saline and acid sulphate soils [6]; bioremediation of agrochemicals [25, 26]; biological pest control [24]; and on- and off-site heavy metal pollution control [6, 26] amongst others.

2.2.1. Erosion and sediment control

Erosion, which is simply the washing away of soils by ‘agents’ such as water and wind, is a phenomenon that has ravaged so many lands, resulting in soil degradation and consequently low crop yield. According to National Research Council [10], it is among the most devastating environmental disaster for many developing countries and it results in loss of huge amounts of valuable soils which are key to agricultural production. Management methods could be expensive and sometimes less effective. However, Truong [27] reported that both research and field results in Australia, Asia, Africa and South America show that in comparison with conventional cultivation practices, surface runoff and soil loss from fields treated with vetiver grass were significantly lower and crop yield was much improved. **Figure 2** illustrates the processes of erosion and sediment control under conventional cultivation practice and vetiver grass system.

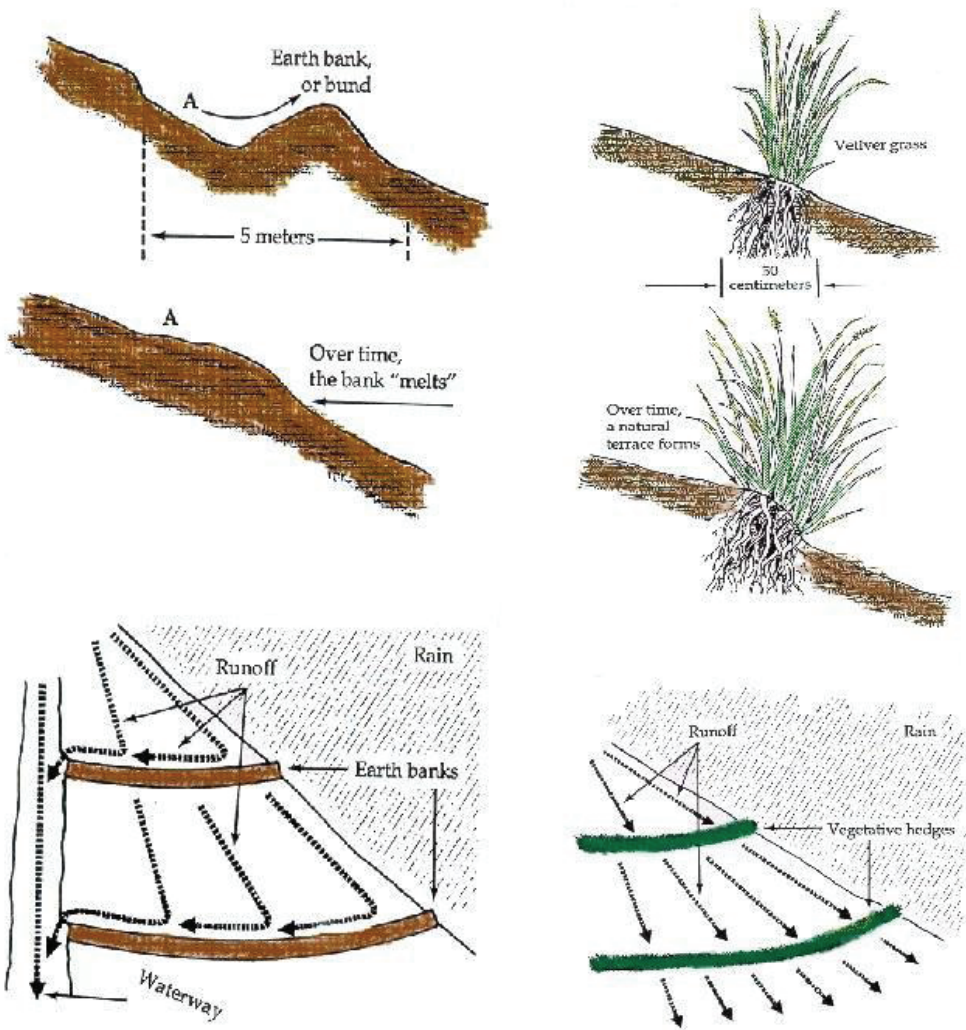


Figure 2. Comparison between conventional terrace/contour system and Vetiver system in soil and water conservation (adapted from Ref. [9]).

V. zizanioides has been reported to reduce soil loss from 11 to 3 t ha⁻¹ [10]. They explained that vetiver is suitable for erosion and sediment control because it slows runoff and gives the rainfall a better chance of soaking into the soil instead of rushing off the slope. According to Truong and Loch [9], when vetiver grass is planted in single or multiple rows on the contour, it forms a protective barrier across the slope, which slows the runoff water, thereby causing sediment to be deposited. They further explained that 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 or without being concentrated in any particular area.

According to Refs. [21–23, 26, 28–30], results over the last 10 years have showed vetiver grass to be very successful in reducing flood velocity and limiting soil movement, with very little erosion in fallow strips. In Rao et al. [31], relative to control plots, average reductions of 69% in runoff and 76% in soil loss were recorded from vetiver plots. In Nigeria, Babalola et al. [3] demonstrated the usefulness of vetiver grass as a soil and water conservation measure in the Nigerian environment. They established vetiver strips on 6% slopes for three growing seasons. The results of the study showed that vetiver grass ameliorated soil physical and chemical conditions, reduced soil and nutrient losses, and increased soil moisture storage by a range of 1.9–50.1% at various soil depths for a distance of 20 m. Other research studies that have been conducted on the use of vetiver grass for soil and water conservation in Nigeria include Refs. [21–23, 26, 32, 33]. **Table 2** shows a summary of the effects of vetiver grass and conventional systems in soil loss and runoff control.

2.2.2. Rehabilitation of saline and acid sulphate soils

Salinity, which is the amount of dissolved salt content of a soil or water body, is a major challenge confronting agricultural production especially in semi-arid regions of the world with respect to crop. According to Truong and Baker [35], vetiver grass that could cope with saline soils has been successfully employed in the rehabilitation of salt-affected lands. This may be due to its high tolerance to salt-affected soils. In Truong [36], it was reported that with a salinity threshold level at $EC_{se} = 8 \text{ d Sm}^{-1}$, vetiver grass compares favourably with some of the most salt-tolerant crops and pasture species (such as Bermuda grass (*C. dactylon*) with threshold at 6.9 d Sm^{-1} ; Rhodes grass (*C. guyana*) at 7.0 d Sm^{-1} ; Wheat grass (*Thynopyron elongatum*) at 7.5 d Sm^{-1} ; and barley (*Hordeum vulgare*) at 7.7 d Sm^{-1}) grown in Australia.

Country	Soil loss			Runoff		
	Control	Conventional	Vetiver system	Control	Conventional	Vetiver system
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%)*	16.8	12.0	1.1	88	76	72
Venezuela (26%)*	35.5	16.1	4.9	NA	NA	NA
Vietnam	27.1	5.7	0.8	NA	NA	NA
Bangladesh	NA	42	6–11	NA	NA	NA
India	NA	25	2	NA	NA	NA
		14.4	3.9		23.3	15.5
Nigeria (Flat)	NA	NA	1.25–10.3	5.3–15.7	NA	1.15–4.07
Nigeria (Mound)	NA	NA	0.68–5.00	15.7–26.5	NA	0.72–4.85

Note: NA, not available (source: Ref. [34]).

*Land slope.

Table 2. Comparison of soil loss and runoff control under conventional and Vetiver grass systems.

On the other hand, acid soils which constitute a major part of arable lands in Africa and Asia are highly erodible and difficult to stabilize and rehabilitate [27]. However, vetiver has been successfully used to stabilize and rehabilitate a highly erodible acid sulphate soil, where the actual soil pH was about 3.5 and oxidized pH was as low as 2.8 [4, 37]. When planted on saline and/or acid sulphate soils, vetiver grass can effectively absorb plant available sodium and metals that contribute to soil salinity or acidity, thereby rehabilitating these soils [35]. Also, the tensile strength of its root system can also contribute to increasing soil strength against runoff and erosion, thus stabilizing the soil slope.

2.2.3. Bioremediation of agro-chemicals

Agro-chemicals (pesticides, herbicides, and even fertilizers) have been reported to adversely affect soil properties and water quality. This adverse effect is finally expressed in the quality of crop produced. According to Truong [27], vetiver has played an important role in the decontamination of agro-chemicals due to its ability to retain them within its system, thereby preventing them from contaminating and accumulating in soils and crops. **Table 3** shows the threshold levels of heavy metals to vetiver grass. According to Refs. [18, 25], research conducted in cabbage crops grown on steep slope (60%) in Thailand indicated that vetiver hedges had an important role in the process of captivity and decontamination of agro-chemicals, especially pesticides such as carbofuran, monocrotophos and anachlor. According to Truong et al. [15], planting vetiver grass across drainage lines could serve as a living filter for capturing unwanted foreign chemicals or contaminants before they reach non-polluted soil and downstream areas.

2.2.4. Biological pest control

Insects and pests are two of the most destructive biological pests known to cause damage to agricultural crops and consequently leading to reduction in crop yield. The use of agro-chemicals in

Heavy metals	Threshold levels in soil (mg kg ⁻¹)		Threshold levels in plant (mg kg ⁻¹)	
	Vetiver	Other plants	Vetiver	Other plants
Arsenic	100–250	2.0	21–72	1–10
Cadmium	20–60	1.5	45–48	5–20
Copper	50–100	NA	13–15	15
Chromium	200–600	NA	5–18	0.02–0.20
Lead	>1500	NA	>78	NA
Mercury	>6	NA	>0.12	NA
Nickel	100	7–10	347	10–30
Selenium	>74	2–14	>11	NA
Zinc	>750	NA	880	NA

Note: NA, not available (source: Ref. [9]).

Table 3. Tolerance levels of vetiver grass and other plants to heavy metals.

controlling most of these pests results in adverse effects on both soils and crops. Results of the research carried out in Guangxi University, China, after subjecting vetiver grass to insect attack, showed that of the 79 species of insect found on vetiver rows, only four attacked young vetiver leaves [24]. He explained that due to few insects that could attack vetiver grass, the damage was minimal. Also, the potential of vetiver extract as a natural pre-emergent weed killer was obtained when methanol extracts of its ground stem and root were found to be very effective in preventing the germination of a number of both monocotyledonous and dicotyledonous weed species [38].

2.3. Management of wastewater

Large volume of waste or contaminated water emanating from industrial or domestic discharges could be difficult or expensive to control, especially when released into the environment. In Truong [36], wastewaters can be managed either by disposal (i.e. total elimination or reduction in volume) or treatment (i.e. improving its quality).

2.3.1. Disposal of wastewater

According to Truong [36], vegetative methods are the only feasible and practicable method available for the disposal of wastewater. Vetiver grass has been reported to be more effective than trees and pasture species in the disposal of domestic and industrial effluent. This is because vetiver grass possesses some unique characteristics suitable for environmental protection purposes [39]. Apart from absorbing toxic elements in wastewater, vetiver grass can also absorb large quantities of water, thus reducing the volume of these waters from the environment. Thus, according to Truong [20], the problem of wastewater disposal can be solved by using such water as irrigation water for growing vetiver grass, where it can be absorbed. Effluent discharge was reduced by sub-surface irrigating vetiver grass rows [15]. This could also reduce potential ponding situations which are not usually favourable for most arable crops. It was reported in Truong and Smeal [40] that in producing a massive growth of biomass ($>100 \text{ t ha}^{-1}$), vetiver grass consumes a large volume of water.

According to Truong [36], in quantifying the water use rate of vetiver, a good correlation between water use and dry matter yield of vetiver was obtained. He explained that from this correlation, it was estimated that for a kilogram of dry shoot biomass, vetiver grass would use 6.8 L day^{-1} . Also, Truong and Smeal [40] explained that if the biomass of 12-week-old vetiver, at the peak of its growth cycle, was 40.7 t ha^{-1} , a hectare of vetiver grass would potentially use $279 \text{ kL ha}^{-1} \text{ day}^{-1}$. According to Truong [36], data from a landfill leachate site showed that vetiver grass can dispose up to $3.8 \text{ L m}^{-2} \text{ day}^{-1}$. It was reported in Truong and Hart [41] that where other plants such as fast growing tropical grasses and trees, and other crops such as sugar cane and banana have failed, vetiver grass survived. Vetiver grass of about 100 vetiver stands in an area less than 50 m^2 completely dried up the effluent discharge from a toilet block. In addition, Percy et al. [42] reported that 4 and 2 mL of highly contaminated landfill leachate were effectively disposed in a month in summer and in winter by 3.5 ha planting of vetiver, respectively, while Smeal et al. [43] reported that most industries in Queensland are upgrading their treatment process of wastewater by adopting vetiver grass system as a sustainable means of disposing wastewater.

2.3.1.1. Treatment of wastewater

Vegetative method is generally the most efficient and common method for water quality improvement [36]. He reported that the attributes of vetiver grass indicate that it is highly suitable for treating polluted wastewater from industries as well as domestic discharges. Some of these attributes include its tolerance to elevated and sometimes toxic levels of salinity, acidity, sodicity, and heavy metals. Vetiver can be used to improve wastewater quality either by absorbing pollutants and heavy metals or by trapping debris, sediment and agrochemicals in agricultural lands. In Truong [20], it was reported that growing vetiver grass on effluent is one of the effective low-cost technologies of treating wastewater. According to Truong and Hart [41], planting 100 vetiver grass in an area less than 50 m² completely dried up effluent discharge from a septic tank. An earlier research by Wagner et al. [44] showed the exceptional ability of vetiver grass in absorbing and to tolerate extreme levels of nutrients, Truong et al. [15] stated that nutrients (N, P, Ca, etc.), herbicides (diuron, trifluralin, fluometuron, etc.) and pesticides (α , β and sulphate endosulfan and chlorpyrifos, parathion and profenofos) could be restrained on site if vetiver grass hedges were established across drainage lines (Figure 3).

In China, research showed that vetiver grass can reduce soluble P up to 99% after 3 weeks and 74% of soluble N after 5 weeks [27]. Vetiver grass has also been used to control algal growth. For example, Refs. [45, 46] reported that vetiver grass could remove dissolved nutrients and reduce algal growth within 2 days under experimental condition. In addition, Truong [27] explained that vetiver grass can be used very effectively to control algal growth in water infested with blue-green algae by planting vetiver grass strips at the edges of the streams or in the shallow parts of the lakes where usually high concentrations of soluble N and P occur. The thick culms of vetiver that is just above the soil surface also collected debris

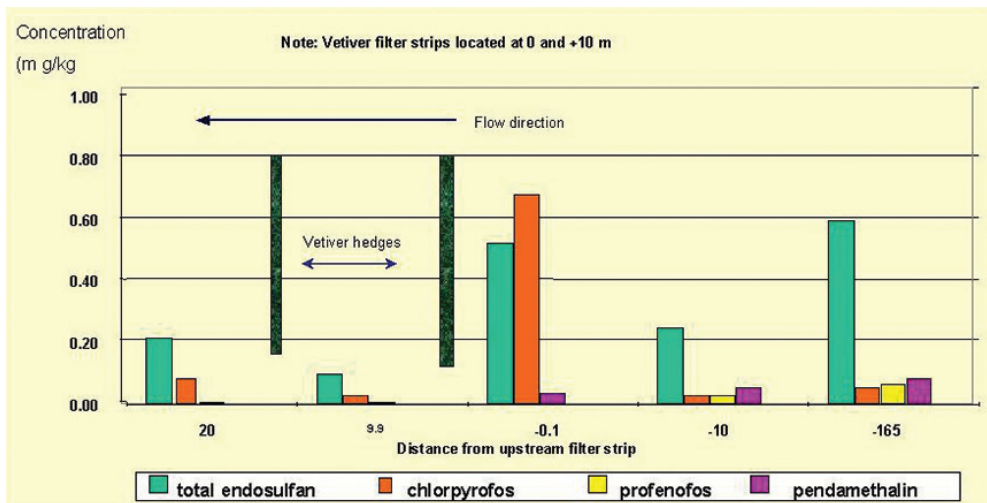


Figure 3. Herbicide concentration in soil-deposited upstream and downstream of vetiver filter strips (source: Ref. [32]).

and soil particles carried along watercourse [47], while Liao et al. [48] reported that with proper planning, vetiver grass technology has the potential of removing up to 102 t of N and 54 t of P yr⁻¹ ha⁻¹ of vetiver planting.

Furthermore, in the purification of wastewater from a pig farm which contained very high N, P, Cu and Zn, vetiver grass showed a very strong purifying ability, with its ratio of uptake and purification of Cu and Zn (>90%), As and N (>75%), Pb (between 30 and 71%), and P (between 15 and 58%) [48]. Concentrations of some toxic elements (Al, Fe, and SO₄) in vetiver grass planted on an acid sulphate soil was found to increase as the plant matures, thus reducing contamination of canal water [49]. Thus, the efficiency of wastewater treatment increases with an increase in the age of vetiver plant [47]. **Table 4** presents effluent water quality prior to and after vetiver treatment. This could be highly beneficial to agriculture especially in the area of irrigation where available water for crop cultivation is fast diminishing as a result of climate change impact and competition from other users.

2.4. Crop yield

The improvement of agricultural crop yield is one of the resultant benefits of the effects of vetiver grass technology on soil and water conservation. This could be beneficial to farmers, especially those farming on sloppy lands that are usually prone to erosion. It was reported by National Research Council [10] that vetiver grass improves crop harvest by reducing crop failure against the dry spell. They also reported that vetiver grass enhances soil moisture for plant use. In Nigeria, Babalola et al. [3] reported an increase in crop yields by a range of 11–26% for cowpea and by about 50% for maize following the application of vetiver grass strips at 20-m intervals against non-vetiver plots on a 6% slope. They attributed the higher grain yield to higher nutrient use efficiency under vetiver grass strips relative to no vetiver strip.

Also, Oshunsanya et al. [32] reported an increase in maize grain yield (13.5–26.6%), and cassava tuber weight (7.9–11.2%) in a maize/cassava intercrop under vetiver grass strips spaced at 5-, 10- and 20-m surface intervals. Another report by Babalola et al. [50] showed

Parameter	Fresh effluent	Results	
		2002/2003	2004
pH (6.5–8.5)*	7.3–8.0	9.0–10.0	7.6–9.2
Dissolved oxygen (2.0 minimum)*	0–2 mg L ⁻¹	12.5–20.0 mg L ⁻¹	8.1–9.2 mg L ⁻¹
5 day BOD (20–40 mg L ⁻¹ maximum)*	130–300 mg L ⁻¹	29–70 mg L ⁻¹	7–11 mg L ⁻¹
Suspended solids (30–60 mg L ⁻¹ maximum)*	200–500 mg L ⁻¹	45–140 mg L ⁻¹	11–16 mg L ⁻¹
Total nitrogen (6.0 mg L ⁻¹ maximum)*	30–80 mg L ⁻¹	13–20 mg L ⁻¹	4.1–5.7 mg L ⁻¹
Total phosphorus (3.0 mg L ⁻¹ maximum)*	10–20 mg L ⁻¹	4.6–8.8 mg L ⁻¹	1.4–3.3 mg L ⁻¹

Note: BOD, biological oxygen demand (source: Ref. [32]).

*Licence requirements.

Table 4. Effect of vetiver grass treatment on effluent quality levels.

that grain yields on plots treated with 4 and 6 t ha⁻¹ vetiver grass mulch were 4 and 47.4% higher than plots treated with vetiver grass strips, respectively. In addition, Laing [51] finally reported that the full potentials of vetiver grass could be harnessed by combining vetiver grass mulch with vetiver grass strips such that vetiver grass strips would reduce soil water erosion, while mulch materials would decompose to improve the nutrient status of the farmland.

2.5. Other uses of vetiver grass

Apart from its unique physiological characteristics, which give it an edge over other grasses as a plant with diverse environmental applications, vetiver grass has also been found useful in a number of ways. Apart from being a soil and water conservation technology, this grass of great utility has been reported to be legally accepted for use as property lines in certain parts of India. Also, in Nigeria the surveyor general has in past permitted vetiver grass hedges as a legal boundary marker. This is because its bases expand so little [10]. It grows so densely that it can block the spread of weeds. For instance, in Zimbabwe and Mauritius, farmers plant vetiver grass around their fields to keep *Kikuyu* grass and Bermuda grass from invading their fields, respectively [10].

Furthermore, National Research Council [10] reported that for several centuries, vetiver grass has been commercially cultivated for its scented oil that can be distilled from its roots. They also reported that it is a treasured ingredient in some of the world’s best-known perfumes and soaps, and largely because of its potential as an export commodity. However, only a handful of countries produce vetiver oil commercially. Although reliable statistics are unavailable, the world production of vetiver oil is estimated to be about 250 tons a year [10]. The annual consumption is estimated in **Table 5**. Other products that could be derived from the vetiver grass include mats, baskets, fans, sachets, window coverings, wall hangings, thatch roofs, lampshades and ornaments which are usually weaved from its roots or stems [10].

Country	Quantity (tons)
United States	100
France	50
Switzerland	30
United Kingdom	20–25
Japan	10
Germany	6
Netherlands	5
Other	30–40

Source: Ref. [10].

Table 5. Estimates of annual consumption of vetiver oil.

3. Conclusions

Vetiver grass technology has been applied globally for controlling soil erosion, stabilizing land and water resources and remediating contaminated lands in order to improve crop growth and yields. It is used as fodder for animal feed, mulch for improving soil moisture and fertility, and fibrous root system for holding soils in place could guarantee food production on a sustainable basis owing to the fact that this grass can withstand adverse environmental and climatic conditions, coupled with quick regeneration after pruning. Thus, when vetiver grass is applied appropriately, it could be a low-cost, simple and easily applicable multi-purpose soil and water conservation tool for sustainable agriculture. It is also a grass of great utility that could provide other means of revenue for local farmers.

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