VETIVER GRASS: A 'CLIMATE SMART', VERSATILE, AND LOW-COST TECHNOLOGY TO HELP ADDRESS GLOBAL SOIL AND WATER ISSUES

A 1993 NRC Panel Chaired by Dr Norman Borlaug (Nobel Laureate) concluded that:
Vetiver is one practical, and probably powerful, solution to soil erosion for many locations

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SUMMARY

Vetiver Grass *(Chrysopogon zizanioides)* has characteristics that make it an ideal plant for mitigating land and water problems under a wide range of ecological conditions. From its first systematic promotion in 1986 as a soil conservation measure in a World Bank agricultural project in India, user-driven field development – backed by research – has developed numerous applications in more than 120 countries across all continents. Vetiver is attractive to local communities and users as it is simple, versatile, and cheap. In association with other technologies, it has proven effective for: raising crop yields and enhancing incomes; water conservation and groundwater recharge; flood, pollution, and pest control; phytoremediation; infrastructure preservation; land rehabilitation; and carbon sequestration. This paper describes a few important illustrations of its use and proposes a strategy for vetiver's future expansion. It concludes that this *'climate smart'* plant can make a significant contribution to mitigating global land and water related problems. In the context of the climate crisis, now is the opportune time for promoting its much wider application to help achieve global environmental security.

1. INTRODUCTION

In 1993, the National Research Council (NRC)[1] published a scientific audit of the safety and effectiveness of Vetiver Grass for erosion control. Dr Norman Borlaug (Nobel Laureate) chaired the Panel which concluded that *'accumulated experiences ... add up to a compelling case that vetiver is one practical, and probably powerful, solution to soil erosion for many locations throughout the warmer parts of the world'*. That the world's soils remain *'under great pressure'* is confirmed by a 2021 UN report.[2]

Since 1993, quietly and without fanfare, vetiver technology (commonly known as the Vetiver System) has spread. It is doing so because it works: those at the coalface have found it affordable, effective, and sustainable in numerous applications and under a wide range of ecological conditions. User-driven field development, backed by research, has

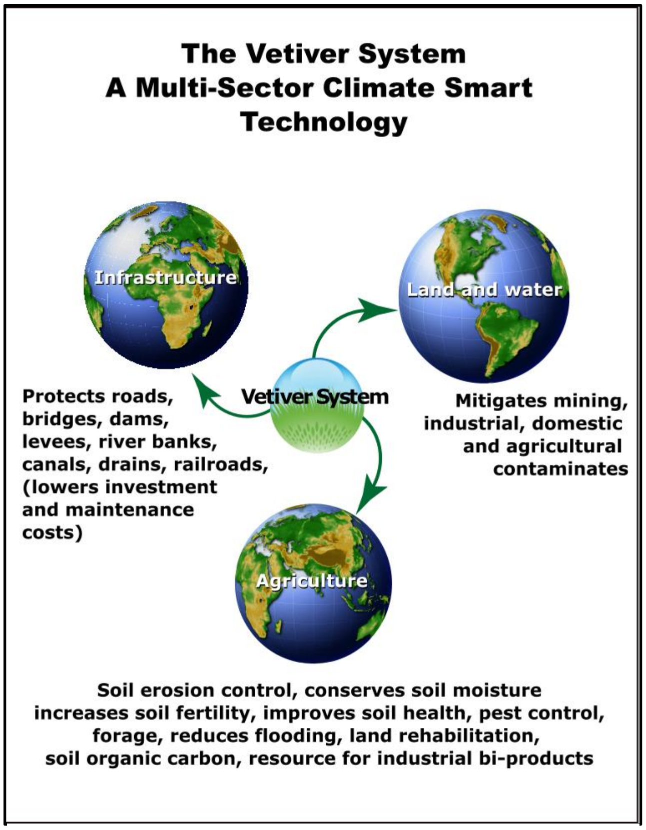

Figure 1. The Vetiver System

been the critical factor that has extended vetiver use beyond erosion control. Communities and users have found the plant effective in association with other technologies for: raising crop yields and enhancing incomes; conserving water; recharging groundwater; managing flood damage; remediating pollution; controlling pests; phytoremediation; the preservation of infrastructure; rehabilitating degraded land and as a pioneer plant for ecosystem restoration; and sequestering carbon. The technology is simple, versatile, and cheap and is readily adopted by users at any scale, whether communal, public, or private. It is of interest and importance to many sectors other than agriculture.

This paper assesses achievements to date and proposes a strategy for vetiver's future expansion. It concludes that this *'climate smart'* plant can make a significant contribution to mitigating land and water related problems. The climate crisis provides opportune time for promoting its much wider application to help achieve global environmental security.

2. THE VETIVER PLANT

Vetiver grass[3], *Chrysopogon zizanioides,* [*,4] a C4 plant related to maize and sugarcane, is a long living *'clump'* grass introduced throughout the tropical and sub-tropical world. The commonest cultivars (non-invasive polyploids) originate from South India. Vetiver grass has a unique combination of characteristics:[5,6,†]

- Forms a dense, ground-level, permanent hedge normally about 1-2 meters high that – when planted along the contour – is an effective filter for reducing rainfall runoff velocity, trapping soil, and enhancing soil moisture.
- Has deep, strong-penetrating, fast-growing, vertical roots (3m or more) with high tensile strength (average 75 MPa).

[*] The genus Vetiveria has been merged with Chrysopogon, hence *Vetiveria zizanioides* is now known as *Chrysopogon zizanioides*. Adams, R. P., R. N. Pandey, M. R. Dafforn and S. A. James. 2003: Op. cit.

[†] Besides the general references indicated, the website (https://www.vetiver.org) refers to research papers that support each of these characteristics.

- Grows under a wide range of rainfall (200 mm to 6,000 mm) and temperature (-15ºC to 55ºC) conditions – freezing winter soils being an exception.
- Adapted to a wide range of soil type (pH 3.3 to 12.5) regardless of nutrient status.
- Is non-invasive[7], having sterile seeds – no stolons or rhizomes – and being multiplied by plant division.
- Does not compete with adjacent crops and often enhances their growth.
- Resists most pests and diseases; provides a habitat for beneficial insects.
- Both a xerophyte and a hydrophyte, it is little affected by droughts or floods. It survives submerged conditions and, being compact with stiff stems, withstands strong water currents and deep flows.
- Tolerates fire, drought, overgrazing, most chemicals, and heavy metals.
- Has the capacity to absorb toxic chemicals and metalloids (due partly to its unique relationship with arbuscular mycorrhiza).
- Has a high biomass production (100 tons/ha), and CO^{2} sequestration at levels comparable to – in many cases greater than – trees.

No other plant is known to share this range of attributes, or to have Vetiver's hardiness and versatility as a conservation plant.

Figure 2: Vetiver Grass

Left: **1-year-old root (Malaysia).**
Above right: **linear section through vetiver hedge showing dense root pattern (Malaysia).**
Bottom right: **30-year-old dense vetiver hedge showing 2m self-developed (Fiji).**

3. USES OF VETIVER

Vetiver has for centuries been cultivated for its essential oil.[*] It may well have had other roles[†,9] but its first recorded use in erosion control occurred early in the 20th century in Fiji, the Caribbean, India and elsewhere,[10] and during the 1950s in Japan.[11] In Fiji it was used on sugar plantations, and it was there that John Greenfield first encountered it. He later incorporated it in World Bank agricultural projects in India.[12,13] From this 1986 revival as a soil conservation measure, other vetiver applications have been developed by end-users in numerous locations in more than 120 countries (www.vetiver.org), often with multiple benefits.

Four examples are summarised below to illustrate vetiver use in: (a) Agriculture (Ethiopia), (b) Infrastructure Protection (Vietnam), (c) Contaminated Water and Land (Australia), and (d) Business and Artisanal Opportunities (China). These are just a small sample of the applications applied in countries across all continents.

a. Agriculture - Ethiopia[‡]

More than 27% of the Ethiopian highlands, some 14 Mha, is seriously eroded. A similar area remains susceptible to erosion, with soil loss from cultivated lands typically ranging between 50-179 t/ha/year.[14] Vetiver was introduced in 1984-85 to the coffee sector, and in 1992 a nursery and outreach programme to farmers was established by an Austrian NGO, Menschen für Menschen. Since then, with Government backing, NGO led interventions (supported by Germany and Sweden) have spread vetiver throughout the country.

Research at JARI[§] has shown that when vetiver hedges were fully formed (by the third year) runoff from bare land was reduced by 70%, and by 90% with both vetiver and coffee on land mulched with vetiver. The corresponding reductions in soil loss (by 95% and 98%) were even more dramatic.[15,16,17] At JARI and elsewhere, natural terraces have formed, one study showing a reduction in average slope of 7% after seven years.[18] On an industrial farm, soil organic matter increased by more than 50% due to soil retention and vetiver mulch.[19] Groundwater recharge also increases and in one locality vetiver contributed to the recovery of 96% of the springs and associated wetland habitats.[20]

Costs vary – one study found that vetiver on farmland in Ethiopia reduced costs by 50-70% compared to the most common physical structures (stone terraces[21] and soil bunds[22]) while savings in maintenance costs were some 85%.[23] Moreover, long lasting vetiver hedgerows have other benefits including pest control, improving soil health (removal of contaminants, enhancement of soil micro flora, fauna and organic matter).[24] In contrast structural approaches have uncertain agricultural impacts and are seldom maintained.[25] Surveys

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[*] Vetiver for oil is preferably grown on well-drained light soils that make root harvesting easier. Haiti and Indonesia are the dominant exporters.

[†] In South India there is an example where it was used to demarcate land ownership boundaries since it stayed where planted and was found to be reliable over generations.

[‡] Vetiver is used in Ethiopia for many other purposes: e.g., slope stabilisation for infrastructure; treatment of effluent from coffee pulping mills before discharge to rivers; and thatching, handicraft, and cultural purposes.

[§] Jimma Agricultural Research Institute.

confirm that farmers are generally happy with vetiver systems,[26,27] whereas farmers develop negative attitudes towards structural measures.[28]

Figure 3. Vetiver Hedge on the Contour
Supporting an excellent adjacent maize crop

Increased soil moisture, soil nutrient recycling (Table 1), and improved pest control (notably of stem borer in maize[29] and – in China – rice [30]), enhance crop growth. In one example, yields of Teff *(Eragrostis tef)* increased by 29% (from 660 kg/ha to 850.8 kg/ha).[31] In another (Table 2) yields of fertilised improved maize increased by 80% when provided with vetiver hedges, and yields of fertilised local maize increased by 59%.

Table 1. Effect of Vetiver Grass Hedgerows on selected Soil Chemical Properties Topsoil Layer (0-30cm) at Haru, Western Ethiopia

Treatments	Parameters					
	pH (H_2O)	Ex. Acidity (meq/100gm)	Av. P (ppm)	Av. K (meq/100gm)	SOC (%)	TN (%)
With Vetiver	5.27	0.19	10.20	0.17	1.61	0.14
Without Vetiver	5.11	0.19	4.22	0.16	0.19	0.15

pH – soil pH: Av. P – available phosphorus: Av. K–available Potassium; SOC–soil organic carbon, TN–total nitrogen.
Source: Leta Hailu, Gizaw Tesfaye, Tesfaye Yaekob. Op. cit. (2020)

Table 2. Farmer Maize Yields: Tulube Peasant Association, Metu District, Ethiopia[32]

Inputs	Yield before 2005 (no Vetiver or structures) Quintal per ha	Vetiver and/or structures	Av. Yield 2007-09 (with Vetiver and /or structures) Quintal per ha	Increase in Yield
Improved seed (25kg) DAP (100kg), Urea (100kg)	40	Vetiver without structures	72	+80%
Improved seed (25kg) DAP (100kg), Urea (100kg)	40	Vetiver with structures	70	+75%
Improved seed (25kg) DAP (100kg), Urea (100kg)	40	Structures only	56	+40%
Local seed (25kg) DAP (100kg), Urea (100kg)	22	Vetiver without Structures	35	+59%
Local seed (25kg) DAP (100kg), Urea (100kg)	22	Vetiver with Structures	32	+45%
Local seed (25kg) DAP (100kg), Urea (100kg)	22	Structures only	30	+36%

Supported by Menschen für Menschen (MfM): approx. 30,000 farmers
Source: Terefe. T.N. Op. cit.

b. Infrastructure Protection – Vietnam

Typhoons, flash floods, and associated landslips are common in Vietnam. Vetiver has been used for slope protection and disaster mitigation in many contexts, [33,34] with technical guidelines issued in 2018[35].

The most widespread application has been for roads. Vetiver has successfully protected much of the Ho Chi Minh Highway,[36,37] a 3,200 km two-lane highway (being upgraded to eight-lanes) with 1,700 km of connecting roads. Construction began in 1999 along the famous Vietnam War trail.[38] It passes through steep, rugged terrain with annual rainfall of 1500-2500 mm, and costly structures often failed during the typhoon season. Vetiver trials began in 2002 and in 2003 the Ministry of Transport approved vetiver as the preferred erosion control measure, supported as needed by structural elements. Initial results were positive and 15 years later more than 1000 km remained effectively stabilised. Over time, vetiver enabled local species that often shaded it out though vetiver persists where local species do not return. More recently, a soil nail/vetiver combination (see Figure 3, bottom left) has been shown (Laguna Project) to be highly effective under extreme conditions on coastal and nearby roads, costing 10-33% less than conventional structural alternatives (soil nail with concrete beam, shotcrete, or gabion mat).[39]

Figure 4. Bio-engineering Uses in Vietnam

Top left– Vetiver by itself (HCM Highway).
Top right – Vetiver supported by toe wall (HCM Highway).
Bottom Left – soil nail with Vetiver (Laguna Project).
Bottom Right– Canal Bank Stabilisation (Central Vietnam)

Besides roads, the most extensive applications are for riverbank and canal-bank stabilisation, and for river and sea-dike erosion control. A review of two disaster mitigation projects in Central Vietnam (Quang Ngai, Danang) funded by Australia, was undertaken ten years after planting,[40] concluding that vetiver was highly successful in protecting river and canal banks from flash flood and saltwater intrusion in these low-lying areas of coastal central Vietnam. There were no significant failures though performance was influenced by the extent of community involvement. After initial tests in the Red River and Mekong deltas, programmes are planned for land stabilisation in these huge areas and to guard against saltwater intrusion as sea levels rise.

c. Phytoremediation – Australia

Phytoremediation uses plants to remediate polluted wastewater and contaminated land. Due to vetiver's extraordinary attributes – growth under extremely acidic to highly alkaline soil regardless of nutrient status, its high tolerance to most chemicals, and its uptake of heavy toxic metals – vetiver can treat both urban and industrial polluted wastewater e.g., from abattoirs and food processing plants. Vetiver can also treat contaminated land by removing contaminants or stabilising the site preventing offsite pollution. Examples include contaminated mining lands; landfill leachate, food processing plants and extremely contaminated industrial waste dumps; and the treatment of effluent from sewage and septic systems. [41]

Vetiver has been shown in Australia to reclaim contaminated mining land.[42] Examples include:

- Highly alkaline fresh mine gold tailings, that are low in plant nutrients and high in sodium, free sulphate, and total sulphur.
- Old gold mine tailings that in contrast are highly acidic due to high sulphur content, being also low in plant nutrients and high in heavy metals.
- Coal mining overburden, that is saline, highly sodic, with high levels of soluble sulphur, magnesium, and calcium but extremely low in nitrogen and phosphorus.

Figure 5. Phytoremedial Uses in Australia

Left: hedgerows constructed as wetlands, treating tertiary effluent from a community septic tank.
Right: vetiver on floating pontoon removing contaminates from water, incl. nitrates & phosphates.

- Bentonite mine tailings, that are highly erodible and sodic, also high in sulphate and low in plant nutrients.
- The residue of bauxite processing known as 'Red Mud', which is highly caustic.

Most contaminants accumulate in the roots where they generally remain indefinitely on site. In principle, roots can be incinerated though this is seldom done. Contaminants also move in low amounts to the leaves which can still be fed to livestock or mulched

Vetiver has also been employed to reclaim land contaminated with industrial wastes, including a landfill site created to store rejects and solid waste from a major explosive manufacturer in Central Queensland contaminated with extremely high levels of ammonia and nitrate; and the waste dump of a fertilizer factory, also in Queensland, which was heavily contaminated by heavy metals and nutrients, notably phosphates.[43] Table 3 shows the exceptional tolerance of Vetiver to various heavy metals, as compared to other species.

Finally, vetiver has been used in sewage treatment. In Toogoolawah, Queensland, it replaced a poorly performing conventional treatment plant discharging into a wetland, leading to reductions of 88% in nitrogen, 81% in phosphates, and 78% in faecal coliforms (cfu/100ml) in the system discharge.[44] In Boonah, Queensland, a Vetiver System with the capacity to dispose 600,000 l/day sewage effluent was adopted that saved greatly on construction and maintenance costs while upgrading the plant to comply with new EPA regulations.[45] (See below reference to community based sewage plants in South China).

Table 3. Threshold Levels of Heavy Metals to Vetiver Growth (compared with other species)

Heavy Metals	**Threshold Levels in Soil ($mgKg^{-1}$)**		**Threshold Levels in Plant ($mgKg^{-1}$)**	
	Vetiver	Other Plants	Vetiver	Other Plants
Arsenic	100-250	2.0	21-72	1-10
Cadmium	20-60	1.5	15-18	5-20
Copper	50-100	na	13-15	1.5
Chromium	200-600	na	5-18	0.02-0.20
Lead	>1,500	na	>78	na
Mercury	>6	na	>0.12	na
Nickel	100	7-10	347	10-30
Selenium	>71	2-14	11	Na
Zinc	>750	na	880	na

Source: Baker and Eldershaw 1992[46]

d. Business Opportunities and Artisanal Uses – China

Vetiver was introduced into China in a 1988 World Bank project.[47] At first, it made slow progress but once the China Vetiver Network (www.vetiver.org/CHN_resdev.htm) was formed in 1996, interest quickened, and the technology is now adopted – especially in South China – over a full range of applications. This has been by supported by extensive academic research in Chinese institutions.*

* An unsourced list of research papers in Chinese journals numbered 34 in 2016 and 37 in 2017.

Of note has been interest by private investors. By 2003, at least ten private companies had been set up across South China. Many established vetiver nurseries and participated in highway stabilisation projects, with the Fujian and Zhejiang Provincial Highways Departments often requiring vetiver in combination with structural measures.[48] The first use for railway embankments was that of the Xinchang Railway Co. for a 638 km railway in Jiangsu and Zhejiang provinces.[49] Another successful example was the 38 km Southern Loop of the Xiang-Gui Railway in the Guangxi Zhuang Autonomous Region which cost 25 yuan/m^2 compared to 90 yuan/m^2 for traditional rubble slope protection. Moreover, maintenance costs have proved far lower since vetiver was introduced in 2008.[50] Perhaps the most successful private company is the Guangzhou Vetiver Grass Environmental Science & Technology Co. which has been involved in a range of projects. For instance, by 2019 more than 80 small rural sewage treatment projects were to be introduced in Guangxi utilising its design, with the same method being extended to five other provinces.[51] Other uses have included treatment of pig farm effluent.[52]

Figure . Uses in China
Top left: Road Stabilisation in Zhejiang Province,
Top right: Rural Sewage Treatment Plant, Caixin Village, Guizhou Province.
Bottom left: Thatching, Rural China,
Bottom right: Handicraft Products, China

A different but popular off-farm use in rural areas has been to utilise dried vetiver grass for thatching, handicrafts, and other artisanal uses to generate supplementary income, mainly for rural women. The King of Thailand took the lead. A network was formed (http://thvn.rdpb.go.th), training manuals were prepared, and training courses were provided in several countries notably China, India and in South America.[53,54] Vetiver may be cultivated specifically for handicrafts but more typically vetiver grown for erosion control and other uses is regularly cut for handicrafts, or for animal feed, mulching etc. The first training programme in China was held in Guanxi in 2007 assisted by a Thai team funded by a German church agency. From there, handicraft activities have expanded into neighbouring provinces, wherever vetiver is cultivated.

4. FUTURE OF VETIVER

Future expansion will depend critically on appealing to local communities, organisations, and enterprises and encouraging them to adapt the technology to address their problems as they see them. Two recent webinars [*'Embedding Vetiver Grass Technology into Farm Systems at various scales under tropical and semi-tropical conditions'* (https://youtu.be/p4OM9Vm1IqE) : and *'Developing, marketing and social impact of vetiver grass-based handicrafts'* (https://youtu.be/dqb3os89sYQ)] illustrate how this might be achieved. Emphasis was given to the technology's versatility, recognising that there are no uniform solutions. Based on an exchange of ideas and experience via the Vetiver Network International, users across the world were encouraged to select components appropriate to their context – from a single intervention to test its local viability to a range of complementary interventions with the aim of attaining multiple objectives simultaneously.

Devolving power to communities is critical, but a step change in the adoption of vetiver worldwide will also require broader initiatives. Since the early 1990s, new uses for the vetiver technology have steadily emerged. Exploiting these opportunities has been underpinned by experimentation and research which should be expanded in support of both known and new uses. Carbon sequestration for instance is a promising emerging use. Grasses can be formidable producers of carbon.[55] If initial results from research with vetiver are confirmed,[*,56,57,58] it could contribute importantly to addressing the climate emergency. Since it may not appeal to the financial interests of a local community, incentives may be needed for it to be widely adopted for this purpose. Other broad initiatives may also be required. For instance, developing and issuing regulations, standards, and procurement procedures – at sectoral, regional, and national levels – may be necessary in some sectors, e.g., for promoting vetiver use for infrastructure protection. To counter rent seeking by officials and commercial interests in expensive structural solutions, community involvement and complementary governance measures will also undoubtedly be needed.

In India, China, and elsewhere, World Bank projects were a crucial vehicle for introducing vetiver technologies in the first place. Similar opportunities will emerge in future, not only in the activities of external lending institutions but in those of NGOs (as in Ethiopia),

[*] *Miscanthus x giganteus* grown in moderate climates on entire fields has been much studied as a biofuel and carbon sink. Miscanthus and vetiver have comparable qualities though vetiver is planted as hedges which occupy only a small part of the land and has been subject to few carbon sequestration studies. Preliminary results suggest that vetiver in tropical and arid areas produces comparable (perhaps more) carbon than miscanthus in temperate areas, and that both compete with trees when planted as a single field crop.

foreign investors and other international actors. The CGIAR institutions for instance could provide an important research focus for developing improved practices in vetiver and associated technologies. By taking vetiver seriously, they could help spread the technology worldwide through their vast international networks and help ensure that this *'smart'* plant fulfils its undoubted potential for mitigating some of the frightening land, water, and climate problems facing the planet. Moreover, with 30 years of global experience since the NRC report,[59] Vetiver Grass applications should be an important part of the FAO-UNEP Decade of Ecosystem Restoration[60] for it is indeed a plant for the people – easy to use, quickly effective, and low cost.

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