CHAPTER 1

INTRODUCTION AND REVIEW

INTRODUCING THE VETIVER SYSTEM, VETIVER NETWORKING, AGRICULTURAL APPLICATIONS, AND FUTURE USES FOR ENERGY/FUEL AND CARBON SEQUESTRATION

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ABSTRACT

The paper describes briefly the Vetiver System (VS), and how it was developed, marketed, and networked in most tropical and semi-tropical countries of the world over the past 20 years from 1987 to 2008.The paper sets out how VS has multiple applications for the agricultural sector including use for soil and water conservation, soil fertility improvement, pest management, land protection and rehabilitation, stabilization of agricultural infrastructure such as roads, canals, drains and building sites, and for control and clean up of agricultural waste. In addition to these generic sector uses, VS can result in specific income improvements from crop yield increases, and the sale of byproducts that include: forage, thatch, mulch, handicraft materials, aromatic oils, medicines, paper, fuel, and a growing saleable product in the form of plant material to be used by other non agricultural sector VS applications. The paper discusses the use of vetiver grass as a bio-fuel (both as a direct fuel and its potential conversion to cellulosic ethanol) and its overall potential relating to climate change and the sequestering of atmospheric carbon. The future research needs are discussed.

Keywords : Vetiver System: Vetiver grass; soil and water conservation; infrastructure; pollution; waste management; agriculture; bio-fuel, carbon sequestering, climate change.

THE VETIVER SYSTEM

The Vetiver System (VS) is a collection of applications that have significant economic and environmental benefits that are dependent on the use of vetiver grass, Chrysopogon zizanioides.

The Vetiver System is generally applied in the form of a linear narrow filtration barrier (hedgerow), occasionally in stand alone form, using sterile cultivars of vetiver of south Indian origin that are not invasive.

Vetiver System applications developed in India and elsewhere in the tropics and semi-tropics are based on research and experimental data using non invasive cultivars such as "Sunshine", "Monto", and "Natal" or cultivars that are closely related with identical DNA.

Vetiver Systems include applications that cover soil and water conservation, agriculture, slope stabilization, pollution control, disaster mitigation, land reclamation, handicrafts, and other economic uses.

1. INTRODUCTION

The Vetiver System that will be discussed at this workshop had its origins in an initiative that I and my colleagues of the World Bank, who were working in India during the latter part of the 1980s, took to reintroduce the use of vetiver grass hedgerows as a means of controlling soil erosion and for better water conservation. At that time we based the introduction on very positive experience that John Greenfield had had with the technology's wide spread application in Fiji during the 1950s, where it was used to replace costly and not always effective engineered contour terracing systems. We first introduced the concept to World Bank funded rainfed agricultural projects in Andhra Pradesh, Karnataka, Maharashtra and Madhya Pradesh – later to Orissa and Rajasthan. It wasn't long before we found out that farmers in Mysore and Kerala had been using vetiver for centuries to demarcate their field boundaries and to conserve soil. Strangely the practice was not widespread and was certainly not noticed by many agricultural and conservation officials, or even by neighboring villagers! During this period there was some very good research carried out by the state agricultural universities with mostly positive results. However the technology did not develop rapidly partly because farmers were not properly apprised of the technology and its uses beyond conservation, and also because non-project conservation staff and politicians were not very supportive, preferring traditional engineered systems (the latter were heavily subsidized, costly to maintain, and not always effective). Because of this lack of commitment, support and promotion, VS did not spread much beyond the World Bank funded projects. Even so it was a start, and it happened to coincide with an increasing focus on "green technologies".

Table 1. Timeline showing linkage between application, country, conference/workshop, and key players.

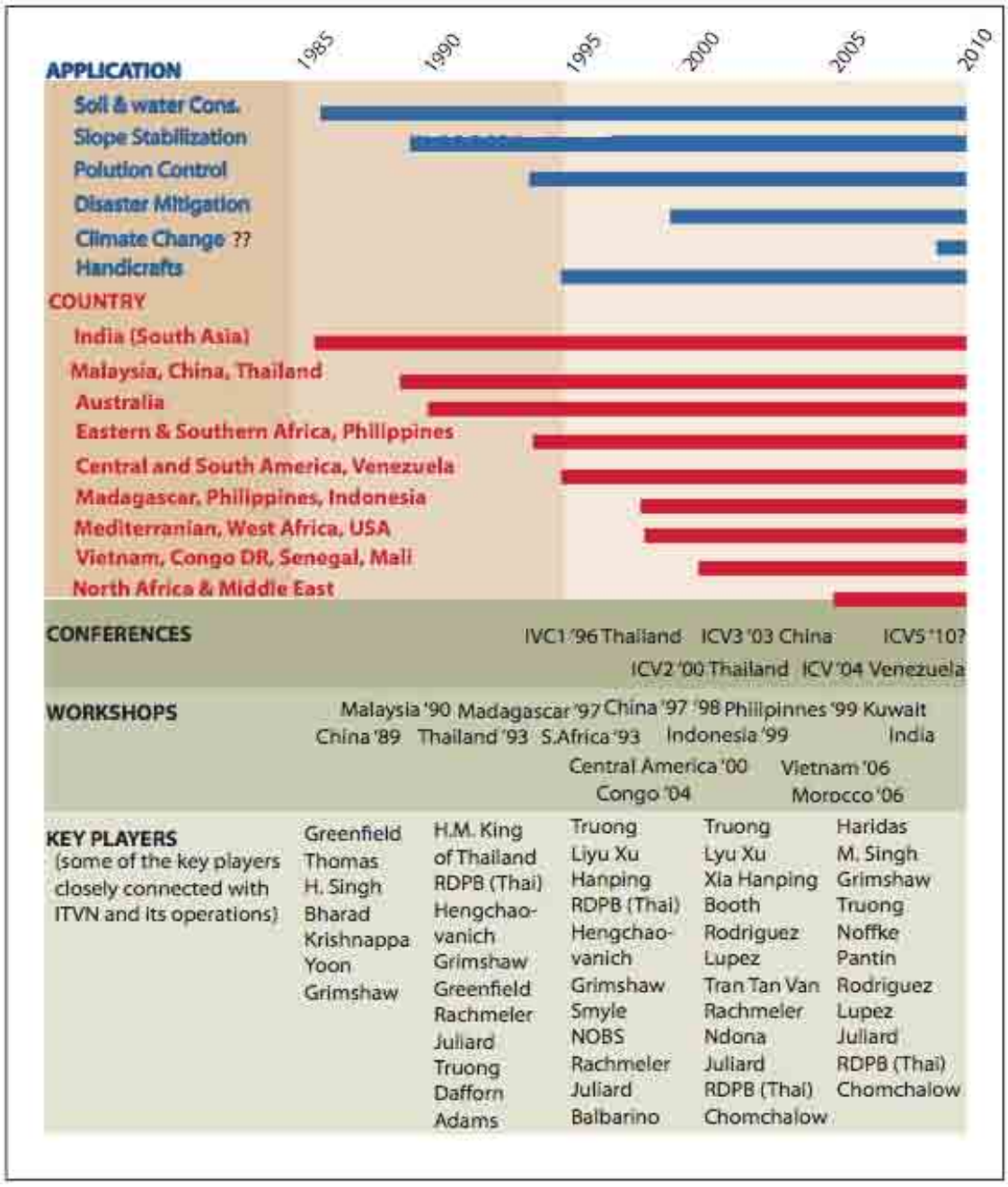

Table 1 above sets out an approximate timeline showing how Vetiver System applications impacted on countries, and the linkage to critical conferences and workshops, like this one, that were critical to the research and development of the Vetiver System. All along there were "Key Players" who were very instrumental in furthering the technology in its different applications. Attachment 1 further elaborates the time line. TVNI was directly involved with all the workshops and conferences. Note direct World Bank support tailed off around 1995.

I would like to take this opportunity to commend John Greenfield and his colleagues, P.K.Thomas (former Conservation Chief of Kerala) and Harbans Singh (former Director of Agriculture – MOA). Thomas and Singh joined the World Bank staff in New Delhi. The three of them were responsible for this initiative in India. I also commend the excellent vetiver research carried out in India by a number of scientists of whom I single out Dr. G.M.Bharad of PVK University at Akola, Maharashtra, and Dr. A.M. Krishnappa head of the operational research projects in Karnataka. Their results showed quite conclusively that vetiver grass hedgerows were an effective means of soil and water conservation. It was this research that laid the foundation for, and provided basic facts that were to interest other potential vetiver users elsewhere in the world.

In 1987, after five years working for the World Bank in India, I returned to Washington DC to head up the Bank's agricultural technical staff for Asia. This gave me the opportunity to move soil and water conservation technology, based on vetiver grass, to other parts of the world. In the early 1990's interest in VS was started to develop in Pacific Rim countries including Australia, Malaysia, Philippines, Thailand, Papua New Guinea, Indonesia, and China. In these countries, through either World Bank funded projects and/or other connections scientists and policy makers showed their interest and support. Our most illustrious supporter was, and still, is His Majesty the King of Thailand who assured that millions of dollars was directed to vetiver research and development in Thailand. Other notable contributions were made by: Dr. P.K.Yoon of Malaysia's Rubber Research Institute, who undertook some outstanding practical orientated investigations into the plant, its management and use; the late Diti Hengchaovanich of Thailand who pioneered the use of vetiver for slope stabilization and who researched vetiver's root tensile strength and its impact on the shear strength of soil; Paul Truong of Australia and Xia Hanping of China, who identified vetiver's extraordinary characteristics that has made it a powerful tool for pollution control; and Tran Tan Van of Vietnam who demonstrated, on a wide scale, how vetiver can be used to mitigate potential damage caused by natural disasters (floods, landslides). Many other people have undertaken useful and supporting research and have shared their work with the worldwide vetiver family. Even more people have put research findings into practice and recycled the results.

In 1994 I retired from the World Bank and established the non-profit, 100% volunteer, Vetiver Network, now called The Vetiver Network International (TVNI). The purpose of the network was to share information about vetiver based technologies, raise funds for research, create technical newsletters and publications, help establish new country and regional networks, create venues for workshops and conferences, and pull the ever growing expansion of vetiver applications and uses into what is now known as the Vetiver System. We have been at this for some 14 years now, and still have many exciting and challenging tines ahead of us. None of this would have been possible if it had not been for thousands of users around the world who see the many advantages of the technology and who have so freely shared with others what they have learned. Today the Network is a "virtual" one, linked together by the Internet with networking nodes and individuals in about 100 countries. The Network has, except for a computer and a desk, no fixed assets, and costs less than US $10,000 a year to operate. Funds have been raised to support vetiver programs that include publications, training, research and workshops like this.

Currently we have a technology that is well researched and very workable, that can impact on many different development and environmental programs in many sectors of the economy. The Vetiver System (VS) is no longer just an agricultural technology under the control of agriculturists, but is a tool for farmers, engineers, water specialists, communities, private sector, construction industry, railroads, mining, utilities, health and many more.

Table 2. Vetiver Systems – Relationship between type of application and grower owner benefits

POTENTIAL BENEFITS TO GROWER OR OWNER - cost savings or net income gain	Investment savings	**Maintenance reduction**	Production increase	**Forage**	Mulch	**Paper**	Energy Biomass	**Handicrafts**	Aromatic Oil	**Medicinal**	Industrial materials	**Planting material**	Carbon credits	**Social Benefits**
APPLICATION TYPES														
Agriculture														
Soil and water conservation	+	+	+	+	+	+	+	+			+	++	+++	+
Land Rehabilitation			+	+	+	+	+	+			+	++	+++	+
Soil Fertility improvement	+	+	+	+	+	+	+	+			+	++	+++	+
Pest Control	+	+	+	+	+	+	+	+			+	++	+++	+
Farm infrastructure Protection	+	+	+	+	+	+	+	+			+	++	+++	+
On Farm pollution control	+	+		+	+	+	+	+			+	++	+++	+
Fish pond enhancement	+	+	+	+	+	+	+	+			+	++	+++	+
Non agricultuture														
Slope protection and stabilization	+	+		+	+	+	+	+			+	++	+++	+
Land Rehabilitation	+	+		+	+	+	+	+			+	++	+++	+
Water quality improvement	+	+		+	+	+	+	+			+	++	+++	+
Pollution control	+	+		+	+	+	+	+			+	++	+++	+
River bank, dam, canal, drain, levee protection	+	+		+	+	+	+	+			+	++	+++	+
Mine tailing rehabilitation	+	+		+	+	+	+	+			+	++	+++	+
Municipal waste stabilization	+	+		+	+	+	+	+			+	++	+++	+
Health (drying up wet areas)	+	+		+	+	+	+	+			+	++	+++	+
Constructed wetlands	+	+		+	+	+	+	+			+	++	+++	+
Coastal protection	+	+		+	+	+	+	+			+	++	+++	+
Specialized planting														
Plant material production				+	+	+		+				+	+++	+
Root production (oil)									+			+	+++	+
Medicinal										+			+++	+
Climate change														
Bio-mass for fuel							+						+++	+
Carbon sequestering				+	+	+	+	+			++		+++	+

+ entirely feasible **++ possible but not always recommended**
+++ definitely sequesters carbon, carbon credits not yet established

Table 2 above provides a matrix to show the relationship between the type of Vetiver System application to potential income and benefits. It underscores the range of possible income that can be derived from each application. Some of the benefits are indirect and secondary to the application's primary use – most applications have a secondary use. Others, such as production

of aromatic oil or specialized production of vetiver plant material, are primary, and have definitive income objectives. Bear this table in mind as the workshop proceeds. We will now turn to the Vetiver System for agriculture and as an important tool to combat climate change.

2. VETIVER AND AGRICULTURE

The vetiver grass species, *Chrysopogon zizanioides* (L Roberty), that is the focus of this workshop, was, until recently, classified as *Vetiveria zizanioides* (L Linus) and in India is commonly known as Khus Khus. Its center of origin is India, and the cultivars that TVNI promotes for Vetiver System applications, are the most research (because they are non-invasive, have good root systems, dense stems and leaves and are the most robust), and can be traced back to south India. These cultivars have names such as Sunshine (USA), Monto (Australia), Valona (South Africa), Karnataka and Madupatty (India) and Fiji. We strongly recommend that only these and similar non-invasive and robust cultivars be used for Vetiver System applications.

The plant, a perennial clump grass, has many special attributes including: its drought tolerance, its growth in a wide range of soil type and pH (pH 3 -11), its tolerance to heavy metals, its ability to grow under very high saline conditions (salinity threshold is $EC_{se} = 8\ dSm^{-1}$) its ability to withstand flooding and submergence for long periods, its very long and strong roots (average tensile strength MPa 75) equivalent to 1/6 the strength of mild steel, its tolerance to most insects and plant diseases, its non-competitiveness with other plants, and its non invasiveness. Although other plants may have some of these attributes we know of no others that combine them all at such extreme levels. It is not difficult to understand why it has been recently described as the "Rolls Royce" of plants.

At this point it is important to address the issue of invasiveness - a question that is regularly raised. The Pacific Island Ecosystem at Risk **(PIER)**, a USDA sponsored unit, carried out a new risk assessment of non fertile Vetiver grass cultivars from south India that are typified by Karnataka and Madupatty (India), Sunshine (US), Vallonia (South Africa) and Monto (Australia) genotypes. Non-fertile vetiver grass, *Chrysopogon zizanioides*, a.k.a. *Vetiveria zizanioides* is rated **minus eight (-8)**. This rating is based on Australian/New Zealand weed risk assessment protocol, modified for Hawaii. Australia and New Zealand both of which are very fussy about importing invasive species allow imports of plants rated +1 or below. North Indian vetiver, from the Ganges and Indus basins, is normally fertile and self-seeding. We do not recommend its use. A DNA testing program developed by Robert Adams and Mark Dafforn showed that most (in the samples tested - 88%) of the *Chrysopogon zizanioides* that was introduced to tropical countries during colonial days were of the same genotype as the infertile south Indian vetiver. Use of similar genotypes around the world has made it much easier to accept and transfer research findings to new locations. In other words "if it will grow - it will work"

In this paper, unless otherwise indicated, "vetiver" equates to a hedgerows (narrow strips about 0.5m wide) of vetiver planted across the slope at a spacing of about 15cm between plants. The distance between rows varies, but is normally equivalent to a vertical interval of not more than 2 meters. Such plantings using good quality plant material and proper management practices appropriate for the area will assure good results.

Why Vetiver?

- We know that there are many plants that bind and protect the soil. We encourage their use where their characteristics meet the need.
- Very few of these plants have been properly studied as to their mechanism of function, alternative applications (if any) and long term reliability. Reliable data under different soils and climate generally do not exist.
- Even fewer plants can create long lasting, non-spreading and effective filter hedgerows that do not compete with adjacent plants.
- Fewer still have dense and deep root systems that create subsurface barriers.
- Vetiver is one of the very few plants that can combine these above and below-ground functions.
- Even fewer plants have application over wide ranges of climate and soil.
- Although there may be a few plants that may be identified and used (as in the case of Switch Grass in the United Sates), these plants do not combine the needed barrier function and longevity, with at the same time tolerance to: extreme and adverse condition and toxic pollutants.
- Most, if not all, alternative plants, in one way or other, exhibit some degree of invasive.
- Vetiver grass when used under the Vetiver System combines these positive characteristics, functions and needs, and is not invasive.
- It would seem that at this time that no serious and quantified alternatives to vetiver grass have been demonstrated that meet the demands of the Vetiver System

On-farm environmental and production benefits

Soil and water conservation: Vetiver grass' most important use in agriculture is for soil and water conservation and the related increase in crop yields. When used for this purpose the plant has to be grown as a hedgerow across the slope (average slope). Details of this application can be found in John Greenfield's handbook: "Vetiver Grass – A Hedge Against Erosion" and in the recently published book by Truong, Tran Tan van, and Pinners: "Vetiver Systems Applications – A Technical Reference Manual". A vetiver hedge acts as a "flow-through" barrier against down slope sediment and water runoff, holding back most of the sediment (as much as 90%) to form natural terraces behind the hedge, reducing rainfall runoff (by as much as 70%), slowing down water velocity, allowing the runoff balance to move evenly down the lower slopes. If correctly spaced the vetiver hedgerows (VI 2m or less) will stop all rilling. The retained sediment contains nutrients and organic matter that would otherwise be lost to the land. Overtime these become natural terraces – in Fiji, on 20% slopes, some of these terrace risers are 3m high. Retained water improves soil moisture and because of the vetiver root's ability to punch through hardpans greatly improves groundwater tables. Crop yield increases have been recorded as high as 50% over control. Below, table 3 demonstrates how vetiver hedgerows will reduce significantly soil loss and runoff. These types of trials have tremendous variation depending on rainfall intensity, soil type etc. However they do provide some order of magnitude and the significance of the impact of vetiver hedgerows. Large-scale trials on micro catchments have not been carried out, but one could expect differences between

conventional systems and vetiver to be even higher. It should be noted that the efficiency of vetiver hedgerows improves with time as they become denser.

Table 3: Effects of VS on soil loss and runoff on agricultural lands

Countries	Soil loss (t/ha)			Runoff (% of rainfall)		
	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			
India		25	2			
Average		14.4	3.9		23.3	15.5

(Truong and Loch, 2004)

The vetiver hedgerows are not only effective on sloping lands, but are also effective against flooding and erosion on "flat" land areas. This was nicely demonstrated on the black cotton soils of Queensland's Darling Downs where narrow (less than half meter wide) hedges were better than the traditional 10-meter fallow buffer strips. Not only did the hedgerows reduce more sediment loss (and thus retain soil fertility), but also because of their inherent stiffness, they reduce water velocity and prevented the lodging of crops. The system is particularly useful where flash flooding occurs. Although not measured, groundwater recharge can be expected to be high under these conditions. In India the Vetiver System has particular application for the black soils of the Deccan Plateau and for most other areas that have rainfed agriculture with 300 + mm rainfall. Of course where associated with supplementary water (irrigation, waste water effluent, water courses and high ground water tables) vetiver will grow in the driest of places as aptly demonstrated in Kuwait (A. Shreekumar and R.C.Suresh – 2007). Vetiver has been used successfully in a number of African countries that have climates not unlike that of India, these include Ethiopia, Kenya, Tanzania, Malawi, Zambia, Zimbabwe, and South Africa. Over the past 10 years there have been some exciting developments in Madagascar involving vetiver for soil and water conservation. It might be summed up by a long-time USAID environment employee (17 years at the helm) -- quote "wished her projects (in Madagascar) to reduce the cutting down of forests were as successful and widespread as vetiver use and application in Madagascar".

Vetiver's use can be extended to the non-arable portions of a farm for gully and land rehabilitation. In the Congo DR some massive gullies on the edge of towns have been stabilized with vetiver grass through community efforts (Alain Ndona). In South Africa farm drains, roads, dams and irrigation canals have been stabilized with vetiver.

In Vietnam coastal sand dunes have been effectively stabilized with vetiver, thus allowing farming activities to proceed without the threat of wind blown sand swamping adjacent fields and crops. In China (Pintang Island) and counties in Fujian province, vetiver hedgerows have been used as windbreaks to protect young perennial crops during their establishment period. As in Vietnam it has

been found in China that vetiver is far more effective as a windbreak against shifting coastal sands than casuarina trees

Soil fertility improvement: Linked to soil and water conservation is vetiver's ability to improve soil fertility. It does this by: (i) reducing sediment loss and the associated nutrients and (ii) through the recycling of nutrients that are out of reach or not available to many other plant species. Vetiver has associated mychoriza that can utilize nitrates and phosphates in the soil. Further research is required in this area. This probably accounts for vetiver's ability, once established, to produce high amounts of biomass without having to resort to additional fertilizer applications. It also means that vetiver can recycle nutrients through mulching practices. Experiments in China resulted in significant increases in soil organic matter and nutrient levels as a result of applying vetiver mulch on red acid (high in aluminum) soils of south China. Soil fertility benefits due to vetiver grass are positive for climate change and could, amongst others increase crop yield, and reduce the level of inorganic fertilizer use. It will also help alleviate against some of the problems created by climate change in areas where future rainfall may be lower (India is one such example).

Pest management: In recent years Prof. Jonnie van den Berg of Potchefstroom University, South Africa has researched the ability of vetiver to act as host to the stem borer moth (*Chilo partellus*). Given the option 90% of the stem borer's eggs are deposited on the leaves of vetiver rather on the adjoining maize and sorghum crops. Once hatched the larvae don't like vetiver's hairy leaf surface and drop off to die. This is known as the "push-pull" system of pest management. Currently studies are taking place in Vietnam to see if the same is true for vetiver and rice. Thus far I understand the results are promising. Additionally vetiver plays host to a number of beneficial insects, including parasitic wasps that reduce pests such as aphids on contiguous crops. Vetiver also provides a good habitat for animals and birds.

Plantation crops: Although vetiver is not shade tolerant (60% maximum) some plantation crops can benefit significantly in association with vetiver. Tea and coffee plantations use vetiver for soil and water conservation and mulch, and benefit from the improved soil moisture, organic matter, and nutrients. Banana growers in Senegal have doubled crop yields when growing bananas under the protection of vetiver. Not only is soil moisture improved but also the incidence of root eelworm is reduced. In India P. Haridas, recently retired from Kanan Devan Hills Plantations Company (P) Ltd. (KDHP) has over the past few years introduced the Vetiver System to all Tata Tea Company's estates in India. We shall hear from him later.

On-farm pollution control: In addition to the above uses vetiver can be used for other activities associated with both small and large farms. It has been shown as an effective means for farm effluent (piggery) clean up. VS can be applied to farm shrimp and fishpond stabilization and clean up; both by bank protection and through floating vetiver rafts that if properly managed can produce up to 150 tons/ha of dry matter. Although labor intensive this biomass can then be fed as forage to livestock. An interesting use of vetiver is its ability to remove excess nitrate, phosphate and pesticide residues that result from farm operations. This will be discussed later in the workshop.

On-farm infrastructure protection: Vetiver Systems can be used to protect many different structures and natural features on a farm. These include building sites, riverbanks and water sources (springheads), dams, canals, drains, and roads. Many of these applications will be discussed in other presentations later in this workshop

Direct cash benefits from sales

We have learned from the above that farmers can expect to gain considerable income from increased crop yields, and potential reduction in the cost of fertilizers and pesticides. However there are a number of other benefits that are direct cash benefits. These include:

Thatch, mulch and forage: Vetiver can be either used on the farm or sold in local markets for all these uses. Vetiver, due to its toughness (when mature) makes an excellent thatch that has a long life since the leaves do not deteriorate quickly (pest resistant). We have already noted vetiver's use as mulch – in China vetiver was more cost effective than rice straw mulch. Contrary to common opinion vetiver is excellent forage if managed properly and cut regularly. The following table 4 compares vetiver grass with Rhodes and Kikuyu grass. It has a higher energy value than the latter grasses, it is more digestible, contains higher levels of minerals, but is lower on protein.

Table 4: Nutritional values of Vetiver, Rhodes and Kikuyu grass, Australia

Analytes	**Units**	**Vetiver grass**			**Rhodes**	**Kikuyu**
		Young	*Mature*	*Old*	*Mature*	*Mature*
Energy (ruminant)	kCal/kg	522	706	969	563	391
Digestibility	%	51	50	-	44	47
Protein	%	13.1	7.93	6.66	9.89	17.9
Fat	%	3.05	1.30	1.40	1.11	2.56
Calcium	%	0.33	0.24	0.31	0.35	0.33
Magnesium	%	0.19	0.13	0.16	0.13	0.19
Sodium	%	0.12	0.16	0.14	0.16	0.11
Potassium	%	1.51	1.36	1.48	1.61	2.84
Phosphorus	%	0.12	0.06	0.10	0.11	0.43
Iron	mg/kg	186	99	81.40	110	109
Copper	mg/kg	16.5	4.0	10.90	7.23	4.51
Manganese	mg/kg	637	532	348	326	52.4
Zinc	mg/kg	26.5	17.5	27.80	40.3	34.1

P**lant material for handicrafts:** Special programs in Thailand and Venezuela have used specially treated vetiver leaves for material of high-end handicraft market. Handicraft made from vetiver benefits those who make the handicrafts and those who produce the raw material. The Vetiver Network International in cooperation with the Royal Development Projects Board has supported the training of Indians and Chinese in vetiver handicrafts by Thai experts. The Women Weavers of India are currently expanding their weaving and handicrafts programs to include vetiver. Zehra Tyabji and Rashmi Ranade, from Women Weavers, received training and are now available to run training workshops in India. In India traditionally vetiver roots have been used for handcrafts, but the proper treatment and use of vetiver leaves results in a much more finely crafted product that can be sold in top end markets where there is a growing demand for "natural" products.

Propagation of vetiver plants for non-agricultural uses: We know there is a large potential for farmer production of plant material for non-agricultural uses. This market could expand quickly and profitably when other sector planners and developers include VS technology into their design specifications. Potential buyers of good quality plant material include: Indian Railways (already have VS specs for vetiver in its design manuals), Public Works Department, State and Central Government highways and roads designers/contractors, irrigation design and construction, building designers/contractors for sites on sloping lands, municipal solid and liquid waste designs, disaster mitigation designers and developers (landslide prone areas, flood areas, storm levee protection, storm refuge centers for people in low lying areas), industrial designers who have to protect unstable and or polluted sites (mine tailings/rehab), and finally landscapers who often are contracted to do some of the above, and can also use the plant for beautification purposes. Another part of society, rural communities and village managers can use the plant and technology for protecting and cleaning up community water sources/sites, such as village tanks, sewage and other wastewater that result in serious health hazards and for stabilizing local infrastructure. Vetiver grass is natures equivalent to steel and concrete. Vetiver System can be used for all these purposes, and nearly always the impact on the environment is for the better.

Both large and small farmers are well set up to be vetiver plant suppliers: the "know how" is easy to learn and comes naturally to most farmers; production is scale neutral and favors farmers near the end use site; and if the product is not fully utilized it can stay in the ground until a new buyer materializes. The profitability is at least as good as an average farm crop (i.e. rice, wheat, maize), often many times higher. I just heard of a farmer in Madagascar supplying 1 million vetiver plants to a mining company in the south of the country. A million plants (slips) can under the right conditions be produced from a ha over a year. At a low price of 1 US cent per slip this order is worth US $10,000. In Italy vetiver slips have sold as high as $15 each! In Australia the farm gate price is about 25 US cents per slip.

Aromatic oil production: Vetiver grass is an aromatic plant whose roots, when distilled, produce the complex low volatile "oil of vetiver". This product is well known in the perfume industry where there is an annual demand of about 120 tons per annum. Its pricing is highly inelastic and relies on low labor costs for the intensive operation of root digging. There have been cases where inappropriate harvesting techniques have resulted in erosion problems. This can be easily overcome by growing vetiver for root harvesting on light sandy soils protected by vetiver hedgerows.

Vetiver oil is made up of many complex chemicals including some that have recently been synthesized (Louisiana State University) and used for termite control. In Senegal farmers deliberately plant vetiver around their houses to reduce termite damage. Vetiver grass derivatives are also used for medicinal and other purposes

Vetiver Systems is a "win win" technology, the end user has a "green", low cost (as much as 90% less than "hard" engineering alternatives), low maintenance and effective solution; the plant material producer increases income substantially. Another big bonus is that the Vetiver System has no carbon foot print -- any carbon emission associated with using, growing, and applying the technology is far outweighed by vetiver's carbon sequestering ability.

Responsiveness by farmers to the Vetiver System: In the past farmers have not accepted vetiver grass technology as much as we had hoped, but this is now changing and we find that where VS has

been introduced correctly and with community involvement and cooperation that many farmers are applying it. I suspect the same is true in India. If we look back we find that vetiver initiatives have come in different forms. In Fiji, during the 1950's the Fiji Sugar Corporation (FSC) had to find ways to stabilize steep slopes that were being opened up for sugar cane. Vetiver hedgerows were tested and worked. Thereafter the FSC would only buy cane from farmers with vetiver-protected land; as a result vetiver became widespread in the sugar areas. Sixty years later we can see the naturally formed vetiver terraces on Google Earth. In India in the late 1980s and 1990s vetiver was introduced to projects as mentioned earlier in this paper. Sadly it was not a great success, but even so it led to the worldwide vetiver initiative and eventually to this workshop! There were a number of reasons for the lack of enthusiasm including: poor farmer education; insufficient community involvement; failure to fully understand landownership issues and farmer needs; lack of government official and political support (soil conservation departments and related research institutions in those days were much more interested in "hard" engineered solutions); lack of interest by other agricultural services (extension agencies); little focus on other uses of vetiver (infrastructure slope protection, pollution control etc.), lack of quantifiable knowledge for designers of non agricultural applications; and generally poor information flow.

Since that time things have changed. The Vetiver Network was established to encourage research and demonstrations into existing and new VS applications and to improve the flow of information, NGOs and bilateral aid agencies that were looking for low cost and effective solutions involving community participation became involved. Thus there were some very encouraging developments in Ethiopia, southern Africa and Madagascar, extending later to Senegal, Mali and the Congo DR. Central American countries, especially after the ravages of the 1998 Hurricane Mitch, with private sector interventions, started using VS for a number of different applications. In East Asia, Thailand, Malaysia, China, Vietnam, Indonesia and the Philippines played important roles in vetiver development. In China, the China Vetiver Network, the South China Institute of Botany and private sector landscapers moved the technology forward particularly for non-agricultural applications. In Indonesia the East Bali Poverty Alleviation Project would not have succeeded without vetiver. In nearly all instances initiatives came about because of the vision of a few committed people who saw that the technology could help their people and country. In Thailand the initiative came from the King of Thailand (a professional engineer in his own right); in Cameroon, from Ngwainmbi Simon, a Baptist medical worker, who now has a country wide initiative in place; and in Vietnam, Tran Tan Van, who being responsible for making country wide recommendations for disaster mitigation, saw the potential of VS; and in eight short years has VS used in 40 Vietnamese provinces for, amongst sea dike stabilization and land slide protection.

In summary, today we have a large range of VS applications being offered to various end users by a various government, non-profit, and private sector organizations, all rather differently motivated, but all with the common objective of using this remarkable plant to its best use. If this is understood, and VS promotion is expanded, the farming community has much to gain.

3. VETIVER AND CLIMATE CHANGE

I have alluded on a number of occasions to the role of vetiver in climate change. Whatever way we use vetiver it is likely to better the environment through reduced soil loss (and related soil fertility) and improved water quality. There are two important areas that vetiver has great potential: as a bio-fuel and for atmospheric carbon sequestering. Both of these applications are possible as stand alone

enterprises, both are complimentary to each other, and both are byproducts of most vetiver applications. A lot more research is needed for both these uses but I will describe below what might be feasible.

Bio-fuel

Furnace Fuel: When grown as a field crop at about 100,000 plants per ha (0.3x0.3m spacing) vetiver can produce up to 40 -100 tons of dry biomass on soils of reasonable depth and fertility. On saline soils in the Dominican Republic dry vetiver biomass production is reported at 70 tons per ha. Vetiver has an energy value of 7,000 BTU/lbs compared to petroleum – 18,000; coal 12 – 13,000; dry wood 8,500; and sugar cane bagasse 4,000. These non-vetiver biomass sources are used as feedstock to generate electricity. Vetiver is well placed as a potential furnace feedstock, and has the added advantage in that it could be grown on marginal lands to feed local steam based generating plants creating energy for nearby communities. In some parts of India it is traditional to move hand-cut sugar cane and grass to nearby cane and paper processing plants. There would be little difference in doing the same for vetiver. The advantage of vetiver feedstock over other fuels is that it is clean, it does not emit noxious chemicals when burnt, and it is entirely renewable and in the burning process does not add net carbon amounts to the atmosphere.

Cellulosic ethanol: In the USA research is being carried out on plants such as Miscanthus, Switch grass, and corn as potential feedstock for cellulosic ethanol plants. Below is a table (table 5) showing the characteristics for an ideal biomass fuel.

Vetiver grass meets all the characteristics of *Miscanthus sp.* and more. Most importantly it is a drought tolerant, long-term perennial crop that need only moderate inputs to be productive. This paper is not to discuss the politics, economics, or methods of ethanol production; others such as Vinod Khosla's paper " A Near Term energy Solution" (2006) and his Power Point Presentation "Bio-fuels – Think Outside the Barrel" have demonstrated the case quite eloquently. Rather we want to promote vetiver's potential over most other plants for cellulosic energy production. There are many areas in India that could be used for mass production of vetiver on a commercial basis. For instance in northwest India there is much poor quality and salinized land that is marginal to agricultural crop production. A lot of this land has a high water table – albeit saline. Once established vetiver would need very little supplementary irrigation to produce high yields of biomass. This biomass could be used as feedstock for ethanol plants. Additionally vetiver would help rehabilitate this saline land so that other it might again be used for profitable purposes. This actually happened in the 1950s on Ussar lands in Uttar Pradesh where vetiver was used to rehabilitate salinized land where little else would grow. A lingering thought wouldn't it be great if Tata's new car – the Nano for the masses could be in the future powered by ethanol derived from vetiver grass.

TABLE I

Characteristics of an ideal biomass energy crop present (+) in corn, short rotation coppice and *Miscanthus*, developed in part from Long (1994).

Crop characteristic	Corn	Short-rotation coppice	*Miscanthus*
C_4 photosynthesis	+		+
Long canopy duration		+	+
Perennial (no need for annual tillage or planting)		+	+
No known pests or diseases			+
Rapid growth in spring to out compete weeds		+	+
Sterile; prevent 'escape'			+
Stores carbon in soil (soil restoration and carbon sequestration tool)		+	+
Partitions nutrients back to roots in fall (low fertilizer requirement).			+
Low nutrient content i.e. < 200 mg MJ^{-1} nitrogen and sulphur (clean burning)		+	+
High water use efficiency	+		+
Dry down in field (zero drying costs)			+
Good winter standing (harvest when needed; zero storage costs)		+	+
Utilizes existing farm equipment	+		+
Alternative markets (high quality paper, building materials and fermentation)	+	+	+

Source: http://www.aces.uiuc.edu/DSI/MASGC.pdf

Carbon sequestering

Vetiver grass has to be one of the world's most unique plants in its range of applications. It also has to be one of the worlds best carbon sequesters. Research by CIAT (Colombia) has shown that deep-rooted tropical grasses in South America can sequester 100 to 500 tons of carbon/ha/year. These grasses do not have vetiver's massive root system. If one extrapolates from this data a single vetiver plant (roots) might sequester (low estimate) 2.5 kg carbon per year. When research is carried out we will probably find this estimate to be low. At 60,000 plants per ha, vetiver could conservatively sequester 150 tons of carbon per year/ha. 1 linear km of vetiver hedgerow (6,000 plants) would sequester 15 tons of carbon per year. 1 square meter (0.3x0.5m spacing) of vetiver would sequester 15 kg carbon per year; 4.5 times more carbon than a fast growing poplar trees per unit area. (Fast growing poplar trees, closely spaced (1x3m) sequester about 10 kg of carbon per tree/year. Vetiver will sequester three times more carbon per square meter and this is probably a conservative estimate and does not include leaf biomass. Of course this is all very tentative, but knowing what we do know about vetiver there would seem to be excellent potential, and a research program is recommended.

"Root derived soil carbon accumulation is being estimated by scientific studies across the globe under both grassland and forests, either in the tropics or in temperate areas. For carbon to truly be sequestered it must be transformed to mineralized carbon aided by the microbial activity in the soil associated with the root zones. One of the reasons for high vetiver plant vigor is a result of its mychoriza (type of soil microbiological organism) association. This association is one of the reasons

vetiver hedgerows produce such high amounts of biomass on the one hand and such high amounts of carbon added to the sequestered soil carbon pool". *Dale Rachmeler (2007)*

We need to learn a lot more about vetiver's ability to sequester carbon and how much, under different climate and soil conditions. Scientists in India would be advised to investigate vetiver's potential. US scientists are working on *Miscanthus sp* and Switch grass because they are known high biomass North American grasses. We should be doing the same for vetiver.

Once we have reliable data on vetiver's carbon sequestering ability we should then be able to propose using vetiver as a plant for offsetting carbon credits. The impact of this would be to increase the profitability of growing vetiver as an energy crop. Some estimates indicate that if income from biomass for fuel is combined with credits for carbon offsetting, economic rates of return would be in the order of 15%. These estimates were made a few years ago when oil prices were less than half of what they are today.

Under current day advanced remote monitoring procedures it might also be feasible to provide carbon credit income to other users of vetiver planting it for land protection, slope stabilization etc.

4. RESEARCH

Ongoing research continues in a number of countries, some is fine-tuning and expanding on what we already know; others such as a Chinese project to develop a cold (winter) tolerant vetiver (interestingly the Karnataka genotype has shown some cold tolerant traits) are new. We need research to learn more about how vetiver can be used for climate change and in particular vetiver's potential as a bio-fuel and carbon sequester. The latter research is quite complex and requires observations under different climate and soil conditions. India is well placed for this, having some good research institutions and a wide range of growing conditions.

We are hoping that the Central Institute of Medicinal and Aromatic Plants in Lucknow may develop a medium term research program that would identify promising cultivars from India's very diverse vetiver population and create a breeding program to develop plants that fit the needs of different vetiver applications and uses. This research would be a major step forward.

5. CONCLUSIONS

This paper has mainly focused on the agricultural aspects of the Vetiver System. More detailed information and data can be found at The Vetiver Network's web site (www.vetiver.org). Some of the most important links on that site are:

Vetiver images by application: http://picasaweb.google.com/VetiverNetwork

Vetiver mini power points by application: http://picasaweb.google.com/VetiverClients

Blog Site: http://vetivernetinternational.blogspot.com/

Vetiver document library: http://www.vetiver.org/TVN_archive.htm

I have deliberately not included references in this presentation as supporting documents can be found on TVNI's website. However, for those of you who would like to follow up on references, you will find many in a paper I presented in 2006 at the Fourth International Vetiver Conference: "Vetiver System: A Green Investment For Sustainable Development" to be found at: http://www.vetiver.org/ICV4pdfs/P02.pdf.

Finally, hopefully, after this workshop many of you will become vetiver practitioners in one way or another. I draw your attention to two handbooks that will help you. The first is John Greenfield's "Vetiver Grass – A Hedge Against Erosion" and the other is the new "Vetiver Systems Technical Reference Manual" that we have given you on CD-ROM as part of the workshop support documents.

The presentations that follow will focus on the other important Vetiver Systems applications using this "Rolls Royce" of plants.

Thank you

ATTACHMENT 1

Vetiver Conferences and Workshops involving directly TVN funds, staff and associates. 1989 - 2008

Conference/ Workshop	Primary local institutions - initiators	Key Introductions	Impact
China – Jiangxi Fujian Workshop - 1989	World Bank Red Soils Project – R. Grimshaw	Introduction of Vetiver Technology to South China agriculture	Initiation of major vetiver initiative in China
Malaysia – International Workshop 1990	Rubber Research Institute of Malaysia – P.K.Yoon and R.Grimshaw	Vetiver basics, plant characteristics, erosion control, road stabilization	Initiation of use of vetiver in tropical plantations and research on tensile strength of vetiver grass roots, initiation of vetiver research in Australia.
Thailand – Workshop 1993	Thailand Land Development Department – Yoon, Grimshaw	Vetiver Basics and erosion control	Resulted in the start of a wide ranging vetiver research program in Thailand
1st International Vetiver Conference – Thailand. 1996	Royal Development Projects Department. The Chaipattana Foundation – HM King of Thailand	Vetiver Basics, erosion control, highway stabilization	Tensile strength of vetiver roots established leading to serious initiative in the use of vetiver for major highway stabilization in SE Asia. Initiation of Australian research on vetiver and heavy metals
Vetiver workshop – South Africa - 1996	Land Resources Institute, University of Petermaritzburg Grimshaw Truong	Vetiver Basics, erosion control, highway stabilization, mine stabilization	Establishment of Southern Africa Vetiver Network and initiation of soil erosion control programs in southern Africa (South Africa, Malawi, Zambia, Zimbabwe)
China Vetiver workshop - 1997	China Vetiver Network Fujian Workshop for South China	Vetiver Basics, erosion control, highway stabilization,	Confirmed a wide range of vetiver applications in China

	Grimshaw	salt water embankment stabilization, wind erosion	and expansion into Guangzhou Province
Madagascar Vetiver Workshop -1997	USAID – CAP project Madagascar – Criss Juliard Grimshaw	Vetiver Basics, erosion control, highway and road stabilization, irrigation and drainage stabilization	Created keen interest in vetiver applications in Madagascar leading to road and railroad stabilization programs
China Highway Vetiver Workshop - 1998	China Vetiver Network – Grimshaw Truong	Special workshop for highway engineers	Expanded highway applications in south China, leading to railroad stabilization
International Erosion Control conference Philippines 1999	International Erosion Control Association – P. Truong	Significant focus on vetiver	Expanded us of vetiver in Philippines and Indonesia
Vetiver Workshop Indonesia 1999	Philippines Vetiver Network – Ed Balbarino	Vetiver Basics, erosion control, highway and road stabilization,	Development of vetiver for poverty projects in East Bali and mining industry
Central America Vetiver Workshop 1999	Post Hurricane Mitch. Latin America Vetiver Network and World Bank. Smyle	Highway stabilization and Disaster mitigation	Expanded private sector involvement in all Central American countries
2nd International Vetiver Conference – Thailand 2000	Royal Development Projects Board. The Chaipattana Foundation – HM King of Thailand	Vetiver Basics, erosion control, highway and road stabilization, river bank stabilization, pollution control, handicrafts and other uses	Resulted in expanded programs in China and SE Asia. Initiation of Vetiver Systems in Vietnam. Research into water quality improvement using vetiver
3rd International Vetiver Conference – Guangzhou China - 2003	South China Institute of Botany, China Academy of Science, Guangzhou Academy of Science The Chaipattana Foundation	Wide range of vetiver applications, special focus on regreening, municipal waste treatment and pollution control	Led to increased research in water quality improvement, sea dike and river bank stabilization, sand dune stabilization. Development of MEDLI criteria for wastewater treatment
Vetiver Workshop - The Democratic Republic of the Congo - 2004	USAID/TVN CLIFS Project, Dale Rachmeler	Range of applications – road stabilization, gulley control.	Initiation of a vetiver demonstration program in the Congo and the establishment of numerous

			multiplication nurseries
International Vetiver Workshop Vietnam – Jan 2006	Canto University, Vietnam Vetiver Network. Government of the Netherlands, Elise Pinners, Paul Truong	Disaster Mitigation. Flood and cyclone damage	Expected to lead to expanded us of vetiver for sea wall and river bank stabilization in East Asia. Production of new technical manuals relating to engineering and water
Arab Region Vetiver Workshop – Kuwait – March 2006	Kuwait Foundation for the Advancement of Science. Grimshaw, Juliard, Truong	Focus on VS applications under hot arid conditions	Expected to lead to a program of research to test vetiver under near desert conditions, including constructed wetlands, oil pollution clean up.
4th International Vetiver Conference – Venezuela October 2006.	Latin America Vetiver Network, Polar Foundation. The Chaipattana Foundation	Theme - vetiver and people	Expected to expand vetiver on a wider base in South America – rural poverty and environmental mitigation.
Vetiver Workshop – Morocco. November 2006	The Vetiver Network - Juliard, Truong, Rachmeler and private sector	Focus on water related issues – vetiver and pollution control	Initiation of the use of vetiver in north Africa particularly in the area of pollution control
First Indian National Workshop	Indian Vetiver Network, Grimshaw, Truong, Booth, Liyu, Chomchalow, Haridas	Vetiver Systems Environmental Protection and natural Disaster Management	Initiation of a major new all embracing initiative for India (and start of research on climate change??)

In addition to the above there have been many in country workshops not involving TVN or its staff and associates directly