SUMMARY AND HIGHLIGHTS OF PAPERS SUBMITTED TO ICV6

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INTRODUCTION

The Vetiver System (VS), which is based on the application of vetiver grass (*Vetiveria zizanioides L.),* was first developed by the World Bank for soil and water conservation in India in the 1980s. In addition to its very important application in agricultural lands, scientific research conducted in the last 20 years has clearly demonstrated that VS is also one of the most effective and low cost natural methods of environmental and infrastructure protection. And recently it has great socio-economic impact on local population and climate change. Historically, the order of development of the five main applications of VS is:

1. **Soil and Water Conservation in Agricultural Land**
   In agricultural land, vetiver hedges provided a very effective and low cost method of soil and water conservation on sloping land, resulted in significant crop yield improvement.

2. **Stabilisation of Infrastructures**

   Its extensive and deep root system provides an ideal tool for erosion control of unconsolidated soil and the stabilisation of steep slopes such as road and railway batters, dam wall, river and canal banks and landslips.

3. **Environmental Protection**
   - ***Phytoremediation of wastewater:*** The Vetiver System can dispose and/or treat wastewater by reducing the volume or improving the quality of polluted water
   - ***Phytoremediation*** **contaminated** l**ands**: Vetiver grass has been used successfully for rehabilitation of mine overburden and phytoremediation of mine tailings.

4. **Socio-economic impact on rural community**
   - ***Poverty alleviation***: Providing income through supply planting materials and handicraft production
   - ***Rural employment*** to rural community particularly women and children

5. **Positive impacts on climate change**

- Disaster mitigation
- Carbon sequestration
- Bio-fuel

PAPERS SUBMITTED TO AWARDS AND PRESETATION

This summary includes all submissions to the King of Thailand Awards, The Vetiver Network International (TVNI) Awards and papers and posters for general presentation. There were altogether 69 papers and 4 Posters from 26 countries and all 5 continents:

- **Asia:** Thailand, Bangladesh, China, Vietnam, Nepal, India, Philippines, Indonesia, Malaysia and Iran
- **Africa:** Ethiopia, Nigeria, Ghana, South Africa and DR Congo
- **America North:** USA
- **America South**. Brazil, Guatemala, Colombia, Peru and Chile
- **Europe**: Italy
- **Oceania:** Australia, Papua New Guinea and New Zealand

There are 65 papers and 4 posters in total (Table 1).

Table 1: Distribution of submissions to ICV6

Category	Applications	Research	Applications	Total
1	**Infrastructure Protection** ***Bioengineering***	3	9	12
2	**Environmental Protection** ***Phytoremediation***	7	7	14
3	**Sustainable Agriculture** ***Soil and Water Conservation***	4	8	12
4	**Socio-economic Impact** ***Poverty Alleviation and Rural Employment***	1	9	10
5	**Research and Innovation** ***Agricultural, industrials and Climate change***	2	10	12
6	**Other Applications** ***Handicraft, Landscaping, Fodder and Medicinal***		9	9
	Total	17	52	69

Overall, both the quantity and quality of the submissions are very impressive, particularly from Thai researchers and practitioners.

In Table 1, the first five categories are fairly evenly spread with Phytoremediation slightly ahead with 14 submissions. However, there is a big difference in the number of Research (17) and Application (52), indicating the awareness and concern in environmental

protection. Details of most of these papers will be presented by the King of Thailand Award and TVNI Award winners and in concurrent sessions.

The followings are some highlights of the submissions:

1. Infrastructure Protection

- ***Bioengineering Research***

The three papers in this group used new and more sophisticated methods to determine the effect of root biomass to enhance slope stability by reinforcing the soil in mechanical and hydrological effects.

- **Apiniti Jotisankasa *et al*** used a mini-rhizotron together with field observation to quantify root-area ratio and the root cohesion that exists in actual slopes. The authors pointed out that there are many aspects that can influence slope stability some of are beneficial and some can be destabilizing.

Certificates of Excellence

The King of Thailand Award for Non Agricultural Application

- Mohammad Islam of Bangladesh developed a device to determine in-situ shear strength of the vetiver rooted soil matrix. It is found that vetiver root enhances the shear strength and deformation capacity significantly. Direct shear tests conducted on reconstituted samples showed that soil samples containing 9% root have maximum strength and deformation capacity. Both analytical and finite element analyses showed that vetiver plantation increases the factor of safety of slope stability significantly. Vetiver roots enhance the bearing capacity of both the dense and loose grounds.

Winner

The King of Thailand Award for Outstanding Application of the Vetiver System

- **Suched Likitlersuang** *et al* used highland Vetiver grass (*Chrysopogon nemoralis*) to investigate the growing rate of the vetiver roots and the root area ratios, and direct shear tests. The cohesion and angle of internal friction of root-reinforced soils were determined from a standard direct shear and a large direct shear apparatus The results indicated that the roots of vetiver grass were fast growing. Shear strength of the root-reinforced soil was significantly increased because of roots bundling as well as the increased number of root hair. Electron microscopic results revealed that the bundling and adhesion contributed from large surface area of root hair can help to improve the slope stability by increasing shear strength of the soil.

Certificates of Excellence

The King of Thailand Award for Non Agricultural Application

The authors mentioned: ***Vetiver grass (Vetiveria nemoralis A. Camus), a perennial grass that had been promoted to help conserve the soil and runoff by the World Bank in***

the 1980s. This is not correct, it is most important to point out that the World Bank only promoted the use of the non-seeded lowland Vetiver grass (*Chrysopogon zizanioides*) not the seeded highland Vetiver grass (*Chrysopogon nemoralis*)

- ***Bioengineering Applications***

The nine papers in this group come from wide range of countries: Asia (China. Thailand and Vietnam); North America (Hawaii) and Latin America (Brazil, Costa Rica and Guatemala), and cover a very wide range of topics for applications in very hostile environment, in combination with geotextiles and hard structures.

- **Tran Tan Van and Paul Truong** present the history of the application of VST for erosion control on the Ho Chi Minh Highway and its review 15 years later. Successes and failures of VST application along the Ho Chi Minh Highway depend on the following factors:

  - The slopes should first be internally stable, as the VST is not immediately effective (slopes can fail before roots have established). Stabilization may take place earliest 3-4 months after planting; hence timing is also very important to avoid slope failure in the first rainy season;
  - Appropriate slope angle should not exceed 45^{o} (H:V = 1:1) to allow for successful establishment and visible effect of the grass on the slope stability;
  - Good protection of the slope toe is a must even with Vetiver grass, be it alone or in combination with other structural measures (Fig.9); and
  - Regular trimming is important to ensure further growth of the grass to achieve good, dense hedgerows etc.

A Review taken 15 years after this successful application of VST can be summarised as:

  - On the whole there are no serious erosion occurs over the length of about 1000km of Sections 1 and 2 of the HCMHW and VST has successfully stabilized these sections of the highway
  - Occasional eroded batters and small slips occurred, partly due to uncontrolled animal grazing and poor internal drainage
  - Vetiver has accomplished its mission as a pioneer plant, providing effective erosion control on very steep and hostile slopes, trapping sediment and runoff water, producing a micro environment to facilitate the establishment of endemic plants
  - Most importantly, in area where local species did not re-established, vetiver persisted and continue to provide protection

- **Aloisio Pereira** explains the principles of Bioengineering and demonstrates the effectiveness of VST when it was applied under a wide range of climatic and edaphic conditions in Brazil, by itself and in combination with geotextile, hydromulching and hard structures.

- **A.Jotisankasa and Narong Chomchalow** give an overview summary of three

main projects related to landslide mitigation using VST which were led by three organizations: Chaipattana Foundation, Office of the Royal Development Projects Board (RDPB) and PTT group.

- Surapol Sanguankaeo et al. showed that in a natural disaster area where VST in combination with geotechnical remedial measures were used the slopes were stable. In addition, there are not any progressive soil mass movements on these slopes. In this project vetiver were planted with suitable closely-spaced plantations (rows 30 cm apart). Shade tolerant species of vetiver were applied in the shaded area of rubber plantations. Geotechnical remedial measures include green gabion wall, green reno-mattress, erosion control mat, hydroseeding, driven soil nail and surface drainage system.

- Jiang Xinmin et al review some factors where vetiver grass protecting side slopes of track beds of 10 railway lines managed by Shanghai Railway Administration from 2000 to 2005. Single shear tests were performed after one year plantation on various soil , ranging from powder sand to clay). The results indicate that shear strength value of soil containing vetiver grass roots is significantly improved compared with that of parent soil. This review was carried out more than 10 after planting. Although they were affected by hyperthermia, dry, typhoons and rainstorms, the Railway Administration states that the conjunction of old and new soils in track beds protected by vetiver grass is satisfactory and side slopes are stable. No erosion has been found. Most importantly, through experimental results and actual field inspection, best results were obtained when vetiver was planted in two sets of double rows.

2. Environmental Protection

This group has 14 submissions, the highest number and evenly divided between Research and Application indicating the awareness and concern in environmental protection.

- ***Phytoremediation Research***

- Porn Phenrat et al conducted a very thorough investigation on the remediation of Phenol contamination on the environment of the community at Chachoengsao province, Thailand. The inevitable side effects of industrial growth and human activity in general contribute enormously to the pollution of our environment. Increasingly organic contaminants have become one of our major concerns. Up to a certain extend we have developed technologies to minimize the harmful effects of inorganic pollutants; we have not adequately dealt with organic pollutants due to their diversity and ever increasing new products. This R&D program highlighted the danger of Phenol contamination, demonstrated methods of dealing with this problem by various Phytoremediation methods, implemented a field-scale treatment program to protect the local community. But most importantly their laboratory-scale experiments identified two possible phases of Phenol degradation by vetiver: Phase I: Phytopolymerization and Phytooxidation followed Phase II a combination of Phase I

with enhanced Rhizomicrobial degradation. The procedural and technological standards of this project should be used as a model for future research in this field.

Winner

The King of Thailand Award for Outstanding Research in Non-agricultural Application

- Sandra Ugalde Smolcz et al conducted research on the remediation of boron contaminated water for crop irrigation using Vetiver Phytoremediation Technology in northern Chile. The valleys of Arica Parinacota Province in Northern Chile present outstanding climatic conditions that allow crop production all year long. However, the valleys are inserted in a desert region where salinity, boron and arsenic are in high concentrations in rivers, as well as in soil, restricting the development of most plant species. This study evaluated an unconventional strategy for boron remediation in irrigation water and agricultural soil of the Lluta valley. Using vetiver pontoons to treat B contaminated water in large pool with five vetiver biomass. The efficiency remediation was 36% for the 15kg biomass treatment. The efficiency removal was 98.4% for lead, 40% for arsenic and 76% for manganese. Yield and quality of corn, lettuce, melon and Cristal chili pepper crops increased significantly when they were irrigated with this treated water. When irrigated with different boron concentrations after 3 months the B levels in soil and leaves were up to 96.5%. These results indicate that Vetiver Phytoremediation Technology is capable of remediating B toxicity, allowing the introduction of new crops and improvement of crop yields

- **Doan Chi Cuong et al** studied the effects of sea water salinity on the growth of vetiver grass to solve problems of pollution in estuaries - where water quality is often affected by the activities of human and industrial, agricultural productions, which have increasingly become more acute. Results show that the growth of vetiver affected by the level of sea water salinity and vetiver grass is capable of growing ***in sea water salinity ranging from 0-19.64 dS/m (0-11 ‰).***

- Nandani Ghimire et al in Nepal assessed the efficiency of Vetiver grass (*Chrysopogon zizanioides*) and *Phragmites karka* (Common reed) in a constructed wetland consisted of four wetland cells separated by plastic lined earthen bunds and planted with Vetiver, Common reed, Both (mixed) and none (control). Growth rate was found greater in the Vetiver than the Common reed though it showed slower development in the mixed pond for the first two months. Decay and rebirth was continuous in Common reed while Vetiver survived 100% though proper hedge development was not seen in the mixed plantation. Efficiency of vetiver on wastewater treatment by reduction of nutrients and chemicals from the water was found greater than that of Common reed. Mixed pond with both Vetiver and Common reed can be an intermediate solution for an over all good wastewater treatment system for those who donot have access to required number of vetiver saplings for their wastewater treatment. On the basis of site observation, experiments and analysis of data, it was concluded that *Chrosopogon zinanioides* (Vetiver) performed better than *Phragmited*

karka (Common reed) and Mixed plantation (both Vetiver and Common reed) can be an intermediate solution between them in wastewater treatment.

- ***Phytoremediation Applications***

- Benito Castorina compares the efficiency of vetiver and Canola (*Brassica napus* L.) in the phytoremediation and reclaiming a very large contaminated area of land at "Valle del Sacco", situated close to Rome where the natural soil environment had been altered by agricultural chemicals and improper disposal of industrial waste, causing a series of diseases in people and animals. The objective of the project was to investigate the potential for removing pollutants in the soil by both plants. After 5 months, to assess the uptake of elements by the plants a total content analysis was done of the soil, followed by an analysis of the extractible fraction in EDTA. The analytical data obtained were used to determine the Translocation Factor (TF) and the Bio-concentration Factor (BF) of each toxic element for the two plants under the two different agricultural conditions. Pollutants include Mo, Cu, Cd, Pb, Co, Mn, Al, Fe, Ti, V and Zn. Results show that for many elements, vetiver showed a higher BF than canola, but the TF was generally lower compared to canola. Phosphate fertilization increased the TF in both canola and vetiver.

- **Hanijeh Jalalipour et al** from Iran consider that the overall concept of landfill treatment is to keep the entombed waste isolated and to minimize its offsite pollution spreading to adjacent the adjacent environment. In Shiraz 69.1% of its domestic wastes contain putrescible organic matter which produces large quantities of leachate and gas. Construction of conventional leachate treatment plants is limited due to their high cost and leachate characteristics. Therefore, to control the production of landfill leachate, several greenhouse and field experiments on vetiver grass were carried out to determine the possibility of using this technology for vegetative capping the landfill area and its potential to decontaminate the soil around the landfill. Greenhouse experiment results showed vetiver can tolerate irrigation with 45% of leachate (COD 64,000-91,000 mg/L and BOD 16,000-25,000 mg/L) Field experiments showed that vetiver can well adapt to Shiraz landfill conditions and survive. Cultivation of vetiver in large scale offers a pleasant view as an additional advantage, as well as to become a very effective soil and water conservation measure. Therefore, it can be concluded that vetiver planting is the best option for Shiraz landfill capping after closing

- **Chaiwat Phadermrod is** the Manager Padaeng Industry Public Company Limited (PDI), which was established in 1981 to mine and refine zinc metal and zinc alloys. The mining leases and related activity areas covers about 332 hectares. The original surface of zinc ore deposit was on the top of hill. Some parts of the leases and permits have not been used and they are left as natural forest and to be a buffer zone to the surrounding areas. Therefore, only the mined area of about 167 hectares needs rehabilitation. Rehabilitation has been done as soon as possible when each part of mining and related activities finished. PDI started growing vetiver for conserving soil and water and rehabilitation in the last 12 years concurrent with mining operation. A total 19.17 million of vetiver slips were planted.

Therefore, PDI mine is one of the biggest mines in Thailand where vetiver has been grown to protect the environment. PDI mine is planting 1 to 2 millions vetiver slips every year, together with 97,600 local tree species in the same time.

From 1993 to 2014, an area of 166 ha (or 62% of leases) was rehabilitated at the cost of 63 million Thai Baht, from the total 114 million Thai Baht of PDI Mine Rehabilitation Fund. When the mining leases terminate in 2023, the company will return the whole area with plantation forest to the Royal Forestry Department. The company hopes that all stakeholders including the surrounding communities will protect the plantation forestry area after post mining for their own benefits forever.

As results of PDI serious intention to rehabilitate the mined land with vetiver growing project and continue post mine rehabilitation, PDI was awarded the Green Mining Awards for three years between 2010 and 2012. In addition, PDI mine also received the CSR Awards for 4 years (2011 to 2014) from the Department of Primary Industries and Mines, Ministry of Industry. All employees of the company are so proud of these Awards; they want to protect the environment surrounding them for sustainable nature.

- Tran Minh Thao et al. investigated the use of vetiver grass as a phytoremediation method to remove organic matters, heavy metals and aromatic compounds in laboratory wastewater. Sewage effluent, as a source of nutrient supply for plant growth, was firstly fed to two wetland systems: mini horizontal subsurface flow (HSSF) and floating raft (FR) wetlands. Next, laboratory wastewater was added gradually to mix with sewage. Nominal hydraulic retention time in both wetlands is 12 hours.

In HSSF wetland, base materials (gravel and sand), algae, and vetiver were in turn investigated for pollutant removal efficiencies. The results reveal that even with the presences of heavy metals and aromatic compounds, vetiver presented reasonable removal efficiencies of about 62%, 68.6%, and 58.3% for BOD, Total N, and Total P removal, respectively. Base materials showed almost no effect on pollutant removal. Algae were slightly responsible for approximate 6.3%, 16.6%, and 19.7% of BOD, Total N, and Total P removal, respectively. On the other hand vetiver, in term of heavy metals, had an impressive removal efficiencies of 99.2, 95.8, 96.2, and 96.7% of Cr^{+6} (in $K_2Cr_2O_7$), Mn ($MnSO_4$), Fe ($FeSO_4$), and Cu ($CuSO_4$), respectively. For aromatic compounds, the wetland is responsible for 96.8 and almost 100% of correspondingly phenol and benzene removal efficiencies. For microbial aspect, N-fixing microorganisms (e.g. *Azospirillum* sp., *Azotobacter* sp.) and Phosphate-solubilizing bacteria (*Bacillus* sp.) increased gradually in population during domestic wastewater feeding stage. When laboratory wastewater was added, N-fixing and phosphate-solubilizing bacteria were quantitatively decreased slightly while population of *Pseudomonas* sp. increased. Besides, *Zoogloea* sp. was also found increasing throughout the experiment and keeping a stable growth even during laboratory wastewater adding.

In FR wetland, both algae and vetiver were also investigated for BOD and aromatic compounds and heavy metals. The outcomes show similar tendencies in treatment and microbial behaviours as in HSSF wetland. Vetiver grass, mainly responsible for organic matters and nutrients removal, presented slightly lower removal efficiencies than those in HSSF wetland. The average values of removal efficiencies are 59%, 63.5%, and 53.0% for BOD, Total N, and Total P removal, respectively. Algae, also, took minor responsibility for

approximate 3.3%, 9.1%, and 8.9% of BOD, Total N, and Total P removal, respectively. Heavy metals of Cr^{+6} (in $K_2Cr_2O_7$), Mn ($MnSO_4$), Fe ($FeSO_4$), and Cu ($CuSO_4$) were found removing less than in HSSF wetland with average removal efficiencies values of 92.4, 85.1, 91.8, and 91.5%, respectively, by vetiver root. Algae show almost no effect on heavy metals and aromatic removals. The vetiver root likewise plays important role in phenol and benzene removals with values of 91.5 and 96% in efficiency, respectively. N-fixing and phosphate-solubilizing microorganisms, *Pseudomonas* sp., and *Zoogloea* sp. presented similar responses tendencies to different living condition when domestic and laboratory wastewaters, in turn, were fed.

3. Sustainable Agriculture

• *Soil and Water Conservation Research*

- **Tekalign Terefe** conducted a survey on farmers' perception of the role of vetiver grass for Soil and Water Conservation (SWC) and its effect in Tulube Peasant Association, Metu District of Illubabor Zone, Southwest Ethiopia. Land degradation is one of the major challenges in agricultural production in many parts of the world, especially in developing nations like Ethiopia. Even though a number of SWC measures were introduced to combat land degradation, mainly because of high construction cost and lack of skilled manpower, adoption of these practices remains below expectations. By the initiation of the World Bank, since the 1980's vetiver grass as a bio-SWC measure got acceptance and almost 120 countries of the world are adopting and practicing it. Since the early 1990s, vetiver grass is used in Ethiopia as one of the SWC.

Data was collected from 112 randomly selected farm households using structured questionnaires, interviews with government and NGO officials of the area, and workgroup discussions with carefully selected community members. Both qualitative and quantitative methods were used to gather information, and descriptive statistics were employed to analyse and assess farmers' perception on the use of vetiver grass and to identify the major role it played in SWC.

This study identified that vetiver grass is the most cost-effective to produce and most easily handled by farmers of the area. The assessment of farmers' perception on vetiver grass and its use for SWC showed that most of the farmers obtained awareness through the NGOs. However, illiteracy, land size and land ownership problems have hindered further expansion of vetiver grass to the area.

Moreover vetiver grass is a very simple, practical, inexpensive, low maintenance and very effective means of SWC, sediment control, land stabilization and rehabilitation. Farmers who planted vetiver grass on their farmland have benefited both in land management and water conservation; as a result their income has increased and their socioeconomic status in

- **Thanachanok Khamkajorn et al** conducted a study to assess nutrient losses e.g. organic matter, total nitrogen, available phosphorus and available potassium losses resulting from soil erosion under different soil and water conservation measures in upland rubber plantations. Data were collected from an erosion trial on fine-loamy, mixed soil with slope gradients ranging from 18-20%. The 5 treatments were: 1) pure para rubber, 2) para rubber with maize, 3) para rubber with vetiver grass, 4) para rubber with maize and soybean in the dry season, and 5) para rubber with maize and vetiver grass. The results showed that among treatments were significant differences ($p \leq 0.05$) in soil losses. The lowest soil loss was observed with the rubber combined with maize and vetiver grass treatment (6.67 ton ha^{-1}). The soil loss was highest in the pure para rubber treatment (16.9 ton ha^{-1}). The amount of organic matter, nitrogen, phosphorus and potassium losses by soil loss did not significantly ($p \geq 0.05$) differ among treatments, but tended to decrease when soil conservation measures were applied. Moreover, the losses of organic matter (86.3 kg ha^{-1}), nitrogen (14.7 kg ha^{-1}), phosphorus (0.056 kg ha^{-1}) and potassium (*0.71* kg ha^{-1}*)* were observed under para rubber with maize and soybean in the dry season treatment. Therefore para rubber plantation together with soil and water conservation measures utilising vetiver grass are suitable systems that can reduce soil loss and the losses of nutrients by soil loss in the upland rubber plantation.

- **Yuthasong Namsai** studied on the effect of vetiver grass on properties of paddy soil (Roi-Et soil series) and Khoa Dok Mali 105 on rice yield The treatments composed of non vetiver grass with no fertilizer (control plot), non vetiver grass with fertilizer (16-16-8 formula) at the rate of 25 kg/rai , vetiver grass which transferred at 60, 90 and 120 days old with and without fertilizer. The objectives of this experiment were to determine the rice growth and yield , the soil properties changes and economic return. The results appeared that The 120 day old transferred vetiver grass with chemical fertilizer produced the highest average rice yield which was 390 kg/rai and was statistically different from control plot which produced only 308 kg/rai of rice yield. The above ground biomass of vetiver at 90 and 120 day old was not statically different. The soil property changes study were found that the vetiver grass plantation could increase soil pH from 4.0 to 4.2 , organic matter content from 0.5 to 0.54-0.65 % , phosphorus content from 8.5 mg/kg to 16.6-28.8 mg/kg and potassium from 34.0 mg/kg to 37.0 mg/kg. On the economics return study, it was found that the cost of vetiver grass plantation (3,620-4,870 bath/rai) was more than non vetiver grass one (3,420-3,970 bath/rai). The net profit of 120 day old vetiver grass plantation earned highest profit at 2,100 bath/rai while non vetiver grass with fertilizer gave the net profit at 1,950 bath/rai and the 60 day old vetiver grass with fertilizer earned non profit.

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- ***Soil and Water Conservation Applications***

- **Mohammad Golabi** identified the Talakhaya watershed in Rota is as a Coral Reef Management Priority site. Since 2006, resource management agencies including Division of Forestry, Division of Environmental Quality, Department of Lands and Natural

Resources, and the Luta (Rota) Soil and Water Conservation District have collaborated on restoring the Talakhaya watershed badlands in Rota. These agencies have worked with USDA Natural Resources Conservation Service in identifying Best Management Practices (BMPs) and restoration projects. Beginning in 2007, NOAA Coral Reef Initiative (CRI) funds were awarded to CNMI to begin re-vegetation efforts of the badland areas in Talakhaya in Rota. The project will quantify the reduction in sediment by determine the hydrology of the watershed and by measuring the level of sediment that is travelling through the streams and deposited in the nearby bays. The stream monitoring is being compared in areas where no mitigation technique is applied with areas where the Vetiver grass is being planted as a mean of controlling erosion. The analysis of the soil and water sampling from the areas of watershed planted with Vetiver grass will be compared with areas of watershed without any vetiver plantation in order to evaluate the environmental impact of the Vetiver plantation on the watershed as well as the coral reef area fed by the stream water from the Talakhaya watershed area.

The preliminary results of first years' of monitoring showed that re-vegetation could possibly have a positive impact on reducing sedimentation. However, new growth, especially the Vetiver Grass Technology, must have more time to establish itself. In addition, more data is required as re-vegetation is still ongoing and becoming established and may have more distinct effect on reduced sedimentation. Therefore, continued hydrologic and soil and stream water monitoring of the area would be necessary to establish a stronger understanding of the effects of the re-vegetation efforts with regards to sedimentation and stream hydrology. Furthermore, there is a continued need for increased community awareness in order for them to appreciate the effects of conservation and the preservation of natural resources in this island. The efforts of this project should develop a sense of community stewardship for protecting the watershed from further degradation possibly caused by human induced burning as well as other degrading factors in order to protect the coral reef in the ocean surrounding the island.

- **Pinpetch Deelom et al,** demonstrate the outcome of the campaign and promotion of vetiver grass cultivation in Chumphon-Buri District, Surin Province Thailand. Thung Kula RongHai Plain, a vast prairies located in the center of Northeast Thailand, had suffered desert-like condition during dry season and flooding in rainy season. Surin Province which is a part of this plain, Surin is located in Northeast Thailand with the total area about 812,000 ha between in the Mun River in the north Dongrak mountain chain in the south. Surin has a tropical savanna climate. Surin province is recorded as one of the top five provinces with the highest poverty in Thailand during 1998 to 2004. Surin Land Development Station, the office of Land Development Region 3, Land Development Department, Ministry of Agriculture and Cooperative dedicated to promoting vetiver grass information and vetiver cultivation and promotion in land resources rehabilitation in this area. Vetiver grass was cultured and then distributes and gives the knowledge to farmer via training and workshops and demonstration since 2012 until now. The results revealed that the vetiver grass is the good method in land resources rehabilitation. Land resources in the project areas were improved compared to the surrounding area. Moreover, in the second

years of the project, the extended project was enlarging to the neighbouring area. The learning center has been built up under the collaboration between the local people and Surin Land development Station. This learning center is not only learning center for vetiver grass promotion but also the agro-tourism for students, farmers, Governments and Organizations for Soil and Water conservation with sustainable Land Resources Rehabilitation in Northeast Thailand.

- Pradermchai Seangkoovong et al investigated the changes in soil, water and nutrient losses, water content in the soil profile, growth of trees in term of biomass, absorption and storage of carbon dioxide in the plantation planted with vetiver. The runoff and sediment from plantation with and without vetiver were found to be 23.17 and 28.08 mm and 0.367 and 0.518 ton/ha, respectively. Macro nutrients NPK loss in runoff and sediment from plots with vetiver were found to be less than those without vetiver by 0.40, 0.20 and 0.27 kg/ha and 0.29, 0.02 and 0.12 kg/ha, respectively. The amount of organic matter, K, Ca and Mg absorbed in sediment by vetiver were found to be 0.33 %, 13.58, 40.42 and 25.96 mg/kg, respectively. In the dry season, soil moisture in the soil profile of the plot with the vetiver was found to be higher than those without vetiver. As for tree growth, the biomass of tree in plot with vetiver was found to be 1.67 ton/ha higher than in plot without vetiver. The plots with vetiver were found to absorb CO_2 0.283 ton-c/ha higher than those without vetiver. An increase in economic values of planting vetiver in plantation was estimated to be 11,828.81 baht/ha/year.

4. Socio-economic Impact

• *Socio-economic Research*

- **Songkiert Tansamrit** presents a research project on the application of the Vetiver System, combining the integration and binding force of vetiver grass, alongside other vegetation methods, in conjunction with engineering applications, to prevent and rehabilitate shallow landslides on a road embankment which is the only access in and out of Ban Na Tum Village, in Surat Thani Province in Southern Thailand. Vetiver grass and other plants were cultivated on soil-filled plastic flapped sack mounds, engineering application, to allow roots to grow and integrate each other and into surrounding soil thus create binding force to strengthen the road and prevent shallow landslide. As the engineering application gradually deteriorates, the root system acts like a fish net, spreading and engulfing underground structures and fastening them to the earth. Furthermore, manpower is sufficient to pile the plastic flapped sacks and fill them with soil; ideal for where there is no heavy machinery access.

The Community Research Team, led by Mr. Pitipong Kitkarnmoe community's leader, found that plastic flapped sacks, when installed with a drainage pipe culvert, strengthened the damaged area and added stability, raising the safety index from 1.1 to 1.42. The success of the Vetiver System was evidenced in the community being able to witness the rehabilitation of the road embankment into a strong and sturdy state with an operational water drainage

system. They can also see the vetiver hedge planted in rows that locks the soil in place and diverts water runoff at the same time. However, the creation of the binding force of the Vetiver System and how the roots of vetiver and other plants integrate with the plastic flapped sacks structure requires more time. The Vetiver System requires maintenance which will involve an important and learning process.

Winner

The King of Thailand Award for Outstanding Environmental Protection

- ***Socio-economic Applications***

- **Xu Liyu and Huang Biao** report on the application and extension of the Vetiver system for rural development in the mountains of southern China. Early in 1988, the miracle grass vetiver was introduced to China for erosion control and agriculture sustainable development. Since the establishment of China Vetiver Network in 1996, Vetiver System (VS) has disseminated throughout the country. In the recent decades following national economy reform, farmers have increasing interests in clearing forests for commercial tree production, and called it as 'forestry revolution'. They cleared vegetation, built earth terrace and planted tea, mulberry tree, and chestnut, etc. in a large scale. Because this kind of cultivation lacked of protection measures, it usually led to more soil erosion, resulting in the decline of soil fertility. Consequently, the commercial trees cannot grow well. And more often, the soil was usually eroded off before commercial trees and new vegetation grew up. Meanwhile, the resulted soil erosion aggravates sediments deposition in the reservoirs and the lower parts of the river basin and caused disastrous consequence.

To solve this problem, VS was widely used for economic tree protection and formed Vetiver Based Agroforestry System (VBAF) especially when the trees were young. Since vetiver can prevent soil loss from runoff, improve soil moisture, and increase soil fertility the intercropped economic crops can grow much better than usual. In addition, the grass is particularly beneficial to the growth of shade-enduring plants such as tea and coffee. For economic trees planted on new terraces which suffer from disturbance the benefit became more outstanding. Starting from 2000 VBAF has been implemented in Guangxi and Anhui provinces in China.

Because the implement area of the projects was limited in small area while the mountainous area is large in southern China, training and extension would be a critical measure to spread the experiences obtained from the project, especially when the original national extension system met problem during the economy reform. To introduce VS and to extend successful experience many different training courses were organized and extension materials have been produced and wide distributed throughout China, which played an important role in VS and VBAF dissemination. Over 1000 farmers received direct trainings, plus thousands indirect trainees.

To help farmers in poor mountains get rid of poverty and to encourage farmers planting more vetiver for soil conservation vetiver handicraft technology (VHT) was introduced from

Thailand into in Guangxi Province of China in 2007. After that totalling 10 vetiver handicraft training courses on VHT were organized by China Vetiver Network in Guangxi Province of west China and Anhui Province of East China in order to disseminate VHT more widely and rapidly. Totalling over 200 farmers participated in the training courses. All of these trainings generated great interest among female farmers and brought them considerable income.

Winner
The King of Thailand Award for Outstanding On-farm Applications and Socio-economic Impacts

- **Alois Kennerknecht** started working with vetiver in 2007, trying to spread the use of vetiver system (VS) as a way to control the soil erosion in Peru. TVNI website www.vetiver.org gave him information about the plant that he had doubt at first, but practice made him realize that everything was accurate, and found that vetiver had a lot of characteristics as a way to purify water and as an economic landscape resource for any population. The main feature of vetiver is its versatility, having in mind the diverse climatological and geographical areas that exist in Peru, making it a strong, resistant specimen that needs much less water than other plants, and easily adapted to the different locations where it is cultivated.

The applications of VS were made on the villagers' properties, providing him an opportunity to create awareness of the plant. These experiences allowed him to strengthen my knowledge of VS applications in different ways and designs. The development of VS has achieved an impact not only in creating a better landscape, but getting a social impact. VS provides means to improve: 1) health aspects, by purifying the local environment; 2) economic aspects, by making possible the reutilization of water, and 3) improving community aspects, by gathering people to create a social space and activating their interaction. Professionally, his only regret is not knowing about the vetiver and its properties much earlier, which is one of the reason he works intensively in promoting its importance in Peru and the world. Then, he is sure that vetiver will be one day recognized as the solution for water and soil erosion problems as had been the potato for hunger starving in Europe a long time ago.

Certificates of Excellence
The King of Thailand Award for On-farm Applications and Socio-economic Impacts

- **Pintip Thitirojanawat and** Pradermchai **Seangkoovong** established a project to encourage communities nearby water source to plant Vetiver since the budget year 2008 – 2014 with the project objectives:

1. To provide Vetiver sprouts to communities that have risk of soil erosion especially to the river source area, public benefit area and agricultural area
2. To promote habitats and school students to know benefits of Vetiver to preserve water and soil by His Majesty' Initiate and know how to make product from Vetiver's leafs

3. To encourage communities and students to be participated in seeding Vetiver sprouts in the target areas

Department of National Parks, Wildlife and Plant Conservation established 6 Development and Promotion of the Utilization of Vetiver of Forestry Demonstration Centres and also 2 sub-centres, Watershed Conservation and Management Unit and Watershed Management Unit to produce and distribute mainly Vetiver sprouts to the water source area. Until now the project conducted 82 classes with 4,100 participants. Since 2008 – 2014, 31,500,000 Vetiver has been distributed to the communities and in 2014 alone 8,000,000 additional plants were allocated to 142 areas (to 129 communities, 8 schools and 5 temples)

The result of promote Vetiver with the participation by communities in the water source areas has been well executed and received great feedback from communities. There are more and more communities demand for Vetiver sprouts to plant in their areas. However, sprouts still not match to the demand and the distribution to the high ground area still facing with difficulties, asking the centres to assist them.

Roley Nöffke from Hydromulch (Pty) Ltd., Republic of South Africa introduced the Vetiver System to local communities in a project entitled ***A Social Investment Opportunity for Rural Communities In Improving Land Degradation.*** This concept was initiated by the Department of Agriculture, Limpopo Province and Hydromulch (Pty) Ltd acting under the auspices of the Vetiver Network International & The International Erosion Control Association Region 2, for the training of rural communities in various soil conservation measures. Vetiver grass (*Chrysopogon zizanioides)*, is a major component of many vegetation-based bioengineering and conservation programmes worldwide. The Vetiver system is affordable and effective in erosion control and water conservation, soil stabilization, pollution control, waste water treatment, storm damage mitigation and prevention, and many other applications.

Vetiver is also very suitable for use in the tropics, subtropics and other biomes. The plant is sterile (does not produce fertile seeds) and is propagated by small offsets/slips, is non-invasive and easily controlled. However, fertile genotypes (Chrysopogon nigritana) indigenous to Africa can become invasive. It is found in Ngamiland, Botswana, the Grootfontein district of Namibia, Central and West Africa and is not recommended for use outside its domain in the above-mentioned applications. There are many wonderful applications which could be of tremendous benefit to rural communities not only as a source of income, but also as a source of material for handicrafts. Its ability to clean water, react against insect pests and nematodes, ability to recharge ground water, erosion and sediment control are to be noted.

- **Samarang Keunun** used vetiver grass biomaterial from agriculture to develop textile grass fiber by chemical process to extract cellulose and remove chlorophyll, resulting in cellulose lengths of between 3 to 10 centimeters by microscopic measurement. The long section fibers are in bundles and cross-sections of vetiver fiber in polygon-shaped group. The vetiver fibers are hirsute, shiny, non-sulky and inflexible. The vetiver fiber size is rather

large, strong, and tough with a tenacity of 2.11 grams per denier, which is stronger than wool but not as strong as cotton fiber. When the fiber is wet properties are poor in flexibility and toughness. To produce good-quality fiber, it must mixed with cotton fiber in a ratio of 50:50 by hand carding, then using a machine until the fibers are aligned and spun into yarn with a spinning wheel, resulting in thread that is large as fancy yarn suitable for a weft. The vetiver is put in a loom weaving in the thread by using a cotton wrap and vetiver fiber weft, using a small textile machine for blue viscose rayon warp and the vetiver thread weft. The result is a new style of vetiver cloth, with the structure of the fabric quite thick with a rough texture like hemp which looks distinctive and outstanding, and which may be used for many products such as women's dresses, place mats of dining table and other uses.

5. Research and Innovation

- ***R&D Research***

- **Malee Nanakorn et al** in an attempt to improve the salt tolerance of vetiver grass (*Chrysopogon zizanioides* L. Roberty) young inflorescence of Kampangphet 2 (KP2) germplasm were treated with colchicine solution. It was found that the colchicine treatment at 0.2% for 12 hr gave the highest percentage of polyploidy plantlets of approximately 31%. Guard cell length and the stomata density in tetraploids and octaploids were significantly different from KP2 and were able to be used as criteria for screening the polyploidy in this grass germplasm. Fifty-three tetraploid plantlets were tested for their salt-tolerance level using 0, 2.25 and 2.5% NaCl under *in vitro* conditions and 4 accessions (V12, V23, V52, V75) with the highest salt tolerance and those superior to KP2 were selected. The accession V52, V75 and KP2 were transplanted to sand culture irrigated with Hoagland solution and 0, 0.75, 1.0 and 1.25% NaCl to study the effect of salt on the growth and Na^+, Cl^- and K^+ contents. The highest salt concentration that KP2 survived was 0.75% NaCl with lower relative dry weight (RDW) than those of the two accessions which could survive at 1.25% NaCl. Both V52 and V75 had lower Na^+ content in their shoots than in their roots and were able to accumulate high concentrations of K^+ in both shoots and roots. The difference of these two accessions was the site of Cl^- accumulation. V75 accumulated a high concentration of Cl^- in its roots and resulted in lower RDW than in V52. In conclusion, the induction of polyploidy in vetiver grass was clearly able to improve salt tolerance.

Winner
The King of Thailand Award for Outstanding Research
On Agricultural Application

- **Savitree Limtong et al** studied the diversity of yeasts in the external surface of vetiver grass leaf in Thailand by culture dependent method and yeast strains. Leaf surface is known to be colonized by a large number of microorganisms including bacteria, yeasts and fungi. Yeasts belong to either phylum Ascomycota or phylum Basidiomycota, were investigated for their capability to produce indole-3-acetic acid (IAA), a plant growth promoter. Determination of IAA production by the vetiver grass leaf yeasts revealed that only

nine strains produced IAA in the range of 11.0-332.9 mg/l when cultivated in yeast extract peptone dextrose broth supplemented with 0.1% L-tryptophan. They consisted of two strains each of *C. michaelii*, *M. caribbica* and *R. paludigenum*, and one strain each of *C. tropicalis*, *P. kudriavzevii* and new *Rhodosporidium* species. The two strains of *R. paludigenum* produced high IAA including strain DMKU-LV61 produced the highest IAA of 332 mg/l and strain DMKU-LV56 produced 109.9 mg/l.

- **Nguyen Xuan Huong et al** studied the microbial biodiversity in the rhizosphere of vetiver grass by monitoring the composition and distribution of microorganisms in soils taken above and around the rhizosphere of vetiver grass grown in some areas in Quang Nam and Da Nang. The composition and quantity of microorganisms in samples taken from areas planted with vetiver grass were greater than those without vetiver grass. In addition, greater quantity of microorganisms was found on the surface of vetiver roots than in zones further out in the rhizosphere; for example, the microorganism quantity in Phu Tho, Ai Nghia, Lien Chieu and Son Tra were in order of (168,1 – 14 – 12,3) x 10^6 CFU/g; (198,1 – 17,3 – 1,37) x 10^6 CFU/g; (31,8 – 2,8 – 0,27) x 10^6 CFU/g and (28,2 – 2,6 – 0,18) x 10^6 CFU/g, respectively. This increase in soil microbes surrounding Vetiver root zones is most likely due to excretion from the vetiver root system in term of nutrient and oxygen supply.
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- **K. Boonsong et al** investigated the effects from the restoration of deteriorated paddy soil with vetiver (*Chrysopogon zizanioides* L. Roberty) on soil quality, rice production, and methane emissions. The study was conducted in organic paddy field in Cha-am District. The site was divided into two plots of 800 m^2 each. During 500 days prior to this study, the soil in these two plots was treated differently. One plot was continuously utilized for rice production for 3 crops. Each crop, after rice harvesting, sunn hemp (*Crotalaria juncea* L.) was grown as green manure to improve soil. Concurrently, the other plot was withdrawn from rice production and vetiver (Surat Thani ecotype) was planted at 0.3x0.3 m interval with no fertilizer to enhance growth performance. Then vetiver was ploughed under and incorporated into the paddy soil in this plot. In this study, the rice (*Oryza sativa* L.) cultivar Chainat1 was cultivated using broadcasting technique during July to October 2011. Soil properties and rice growth were monitored. The methane emissions were monitored with static closed chamber method in each rice growth stage. The results indicated that soils in vetiver plot had higher redox potential and exchangeable potassium. Moreover, the rice showed higher growth, biomass and production. The average methane emission during the entire growth period of rice from vetiver plot (21.34 g/m^2) was lower than without vetiver plot (34.23 g/m^2). The amounts of carbon accumulation in rice were 453.65 g/m^2 in vetiver plot and 349.52 g/m^2 in the plot without vetiver. In conclusion, the overall results suggested that soil improvement with vetiver had the potential to improve soil quality, rice production, carbon accumulation in rice and mitigate methane emission.

- **K. Wattanaprapat et al** studied the relationship and correlation of vetiver root biomass with soil organic carbon and CO_2 emission in the agricultural areas of the southern part of Thailand and carried out at the Land Development Station, Surat Thani

province in 2008-2010. The objectives of this experiment are compare root growth and biomass of 6 ecotypes of vetiver grass, changes in soil organic carbon and CO_2 emissions from the soil surface, and estimate the correlation between such factors to study changes of soil carbon stock. The experimental design was a randomized complete block design (RCBD) consisting of a control (no vetiver planted) compared with 4 ecotypes of *Chrysopogon zizanioides* and 2 ecotypes of *C. nemoralis*. The result showed that the vetiver root length of the 6 ecotypes were not different and had an average root length of 54.06-58.60 cm. The root length remained constant between 8 months and 24 months during this experiment. The root biomass changes followed a similar pattern to that of root length with no significant differences between 8 and 24 months. The average organic carbon content in the roots is in range of 3.98-5.16 t/ha, and Prarat Chatan ecotype has the highest average organic carbon content at 5.16 t/ha. Soil bulk density increases with the depth of the soil from 15 to 50 cm. Vetiver planting in the soil clearly promotes bulk density decreases, and soil bulk density is highly correlated with root biomass. The soil organic carbon content in the soil surface layer (0-15 cm) is higher than in the deeper layer of this soil. Planting vetiver clearly encourages increases in soil organic carbon, especially in subsoil levels 15-30 and 30-50 cm. The correlation between soil organic carbon with CO_2 emissions from the soil surface is positive. This relationship shows that increasing amounts of soil organic carbon promotes CO_2 emission from the soil surface. Moreover, the correlation between root biomass and CO_2 emission is $Y = 30.36 + 276.0$ ($R^2 = 0.736$). Assessment of carbon stocks in the soil where the six vetiver ecotypes were planted versus the control with no vetiver planted, shows that the amount of soil carbon stock is lost in the control plot equal to -4.19 t/ha. But in the vetiver plots, the amount of carbon stock increased by +2.44 to +6.38 t/ha, especially under the Prarat Chatan ecotype treatment that has the highest soil carbon stock increase at 6.38 t/ha.

- **Mattanaporn Maikami et al** followed up the works conducted by M. Nanakorn et al mentioned above. The *in vitro* screening plants were brought to test in the field for verifying the tolerance under natural conditions which have various factors totally different from *in vitro* conditions. For this, four salt tolerant accessions of vetiver grass (*Chrysopogon zizanioides* (L.) Roberty) were selected and evaluated for their tolerance level in the field. Two accessions, V12 (the most tolerant under *in vitro*) and V52 are diploids and the other two, V23 and V75 are tetraploids. The seedlings were transferred to grow in saline area at Dan Khun Thod district (15˚14'53"N 101˚43'27"E), Nakhon Ratchasima province in the northeastern part of Thailand. The survival rate, number of tillers and plant height were investigated during 8 months and salt ion content was analyzed at 5th month. The result was compared to the original diploid plants or the control (Kampangpetch 2 germplasm, KP2). During 1-5 months after planting (rainy season), the survival rate and growth of selected accessions were found higher than those of the control in contrast with the content of salt ions (Na^+ and Cl^-) in their shoots which were higher. These results indicated that the selected accessions used the salt ions as osmolytes for osmotic adjustment in order to maintain water absorption. Base on survival rate, V52 performed most tolerant to salt during the first five months. However, at 8th month after planting (dry season) as soil EC_{se} increasing, V23 was

the most tolerant accession with 36.1% survival rate compared to 0% of KP2. These results confirmed the importance of the field test and evaluation.

- **Pornpat Nopmalai et al** conducted research on carbon storage and carbon dioxide emission from the soil surface and carbon balance in vetiver grass cultivation at the Chiang Mai Land Development Station, northern Thailand during 2008-2010. The experimental design used was a randomized complete block design consisting of 3 replications with 7 treatments: control (non-vetiver grass) compared with 6 ecotypes of two vetiver species: *Chrysopogon zizanioides* with 4 ecotypes: Sri Lanka, Surat Thani, Mae Har, and Prarat Chatarn. and *Chrysopogon nemoralis* with 2 ecotypes: Prachuab Khirikhan and Roi Et. Results showed that Prarat Chatarn produced the highest biomass of 35.6 t ha^{-1}. The remaining ecotypes produced biomass amounts in the range of 31.2-35.2 t ha^{-1}. Carbon accumulation in leaves and roots of various ecotypes varied with the growth period. The Prarat Chatarn ecotype produced the highest carbon accumulation of 7.45 t ha^{-1}. For the plots with vetiver grass plantings, there was an increased amount of organic matter, soil moisture and decreased soil bulk density compared to the plots without vetiver grass. Mulching with cut leaves increased soil carbon storage. Carbon dioxide emissions in the plots with vetiver grass were higher than in the control plots. For carbon balance estimates, the plots with *C. zizanioides* produced carbon storage of +1.53 kgC m^{-2} y^{-1} and that was higher than for *C. nemoralis* plots with carbon storage of +1.37 kgC m^{-2} y^{-1}. While the plots without vetiver grass caused a soil carbon loss of –0.31 kgC m^{-2} y^{-1}.

- ***R&D Applications***

- **Michael Huffine and David Price,** planted vetiver in California's Mojave desert as a trial for application in ecological restoration. Plantings of vetiver grass species have been used in various tropical situations as "nurse" plants to either jump start native revegetation initiatives or to ensure the continued survival of native seedlings in adverse conditions until they are well established. The High Desert of the Mojave, California, presents unique and extreme challenges for the use of vetiver grass but the potential benefits, should it prove successful, are considerable.
The Mojave River Watershed comprises just over 4,000 km^2 entirely within San Bernardino County, California and ranges in elevation from 427 to 2,590 m. The Mojave River has been severely impacted by anthropogenic development resulting in severely degraded ecosystems, extreme habitat fragmentation and area loss to urbanization, overuse of groundwater, and introduction and establishment of harmful invasive species.

The *High Desert Tall Pot & Mojave River Native Plant Rehabilitation Project* (HDTP & MRNPRP) near Victorville aims to restore the structure and function of parts of the riparian ecosystem after the removal of non-native invasive species by local authorities, and to replace them with phreatophytic native vegetation transplanted from HDTP & MRNPRP project nurseries. The removal of non-native invasive vegetation is well underway, with accessible riparian sites that can support islands of transplanted and seeded native and local plants have been identified in the early stages of the program. A native plants nursery is currently being

established on the site of the Mojave River Campus (a high school), which will also provide a significant education and citizen science component to the project. Next, selected riparian sites will be prepared and "islands" planting and seeding will occur, with intensive monitoring and management, particularly during the establishment phase. Finally, it is hoped that increased involvement from the local community will allow the project to upscale and become sustainable.

Vetiver grass (*Chrysopogon zizanioides*) is being trialed as a tool to contribute in at least two stages of this project. The native plants nursery being established at the campus by students is adjacent to a 45 degree slope, raising fears of erosion. Vetiver grass is being trialed for use as vegetative cover for this area and to provide vetiver slips for later use in outplantings. If this is successful, vetiver grass will be planted in nursery chevrons or wedges about 12 months before outplanting natives in order to develop a semi-protective micro-habitat for outplanting of the other island-guild native plants. It is expected that vetiver grass will provide some level of protection from wind, water erosion and

6. Other Applications

- Alain Ndona from DR Congo presented a Review <***Introduction, Adoption and Expansion of the Vetiver System Technology in Congo-Kinshasa, Congo-Brazzaville and Uganda Republic: experience gained from 2003 to 2014***>. He found various barriers existed at four different major levels: 1) policy makers, 2) infrastructure construction companies, 3) local people and 4) the person or group of people involved in vetiver technology popularization. These four factors simultaneous play a very important role in the success or failure of the adoption and expansion of vetiver technology in any country.

In order to overcome these barriers in any country, not only the advocacy skills and persuasion capacity of the person or group of people supporting vetiver technology, but also the successful demonstrations on small-scale of this eco-friendly technology. These are the main keys to open a large scale adoption and use of vetiver technology in any country.

This approach has been successfully achieved at Congo - Kinshasa since 2003, Congo - Brazzaville since 2008 and most recently in Uganda since 2013, where some projects using vetiver grass were successfully implemented and the adoption and expansion of this green technology in these three countries in Africa are nowadays effective, with more than 35 million vetiver slips used in about 14 different known projects and 28 different partners were involved, through which vetiver technology continues to be disseminated.

Winner

The King of Thailand Award for Outstanding Dissemination and Technology Transfer

- Yoann Coppin founder of La Plantation Bemasoandro, a private company, introduced the Vetiver System Technology to Madagascar, which according to the World

Bank, is one of the most eroded country in the world with an average of 400T/ha/year of soil disappearing in the Indian Ocean each year!! From space, the astronauts can see two land marks made by human on Earth: one is the impressive Great Wall of China, and the other one is, from December to March, the spread of the red sediments to the Sea from erosion derived from rivers around Madagascar. They said « The Red Island is bleeding ».

The agro-environmental degradation is catastrophic: according to a World Bank's study, almost 300 000ha of land are burnt, and 50.000ha of forest disappear each year. Knowing only 10% of the rainforest left. Since its creation, this company has collected, produced, planted or used over 5 million of Vetiver plants and has planted more than 200 Km of Vetiver Hedge Rows. Over the seven years period, La Plantation Bemasoandro has successfully used VST for:

- land rehabilitation and environmental restoration
- slopes stabilization and infrastructures protection
- floods and sedimentation damages alleviation
- water treatment and urban landscaping
- Lavaka stabilization
- Crop improvement and soil conservation
- Riverbanks protection
- Material plant production
- Landscaping

- **Feng Ziyuan** conducted a review of the Vetiver System Technology: application and development in China from 1998 to 2015. Vetiver grass (*Chrysopogon zizanioides*) as early as the 1950s was planted in southern China, mainly used to extract its essential oil (Vetiver oil). Today, China's Zhejiang, Fujian, and Jiangxi provinces are still involved in harvesting vetiver to extract the fragrant oil. Vetiver technology, applied to soil and water conservation projects, was introduced by Richard Grimshaw to China in 1988. Since then, vetiver technologies in China have received large interest by plant community scholars as well as the environmental fields. During this time, officers in the international vetiver network (TVNI) (Richard g. Grimshaw, Paul Truong and the late Diti Hengchaovanich) have offered essential guidance and assistance to vigorously promote and develop Vetiver use in China. Because vetiver is a tropical and subtropical plant, vetiver technologies in China have mainly concentrated south of the Yangtze river basin for testing and application.

Throughout China's 25 year history of vetiver technology, applications have included: slope eatnilisation, vegetation restoration, artificial wetland conservation, water purification and wastewater treatment, as well as the management and development of a comprehensive ecological landscape. During this 25 year span, there have been many successes, failures, and surprises, with positive government support. Today, the central government has a new directive for China's "ecological civilization and beautification", which should help usher in an era of greater development opportunities.

- **David Price and Michael Cochran** report on a project entitled ***Vetiver Initiatives in Papua and West Papua, Indonesia*** Apart from some localized trials at the

Freeport Mine in Timika, these represent the first application of Vetiver technology in Papua. D, Price began using The Vetiver System in 2008 after seeing Vetiver work done in Sumatera during the rebuild after the Asian Tsunami by Norman Van't Hoff of Bali. A small Vetiver nursery was created in Sentani with Bali stock, and this provided the plants for a number of projects focusing on Vetiver use or having Vetiver as an important component.

To date two Vetiver Horizontal Sub-Surface Flow (HSSF) wastewater treatment wetlands have been created for large aviation NGOs. The first used Vetiver Grass to treat effluent from a large hanger facility. Later, due to that project's success another HSSF wetland planted with Vetiver was created in the highlands to treat effluent from accommodation blocks of aviation NGO. Several local community members now use Vetiver to manage overflow of effluent from septic tank systems in flood prone areas. We also used Vetiver plantings in conjunction with rows of rock-filled gabions to arrest severe riverside and cliff erosion at an international school facility in Sentani.

In another large initiative, Vetiver is being used by M. Cochran for community development and erosion control. The rudimentary road system of the *Arfak Mountain* regency of *West Papua*, is a crucial asset, facilitating the provision of resources and services to multiple indigenous people groups and Indonesian immigrants. However it is under constant threat from erosion and landslides and limited resources have prevented the local government from being able to address these issues in a sustainable manner.

The *GPKAI*[1] *landslide/erosion control program* began in 2011 and trains indigenous GPKAI leaders in the application of the Vetiver System (VS), including knowledge of plant characteristics and experience in propagation, extreme slope stabilization (> 45°), and erosion control techniques. The program has successfully established three separate medium-sized nurseries, applied VS for extreme-slope stabilization to several trial sites, has been actively engaging local government since 2013, and is in the beginning phase of partnering with the local government to address the road situation.

The program's goals are threefold: 1) to establish the GPKAI program as a local technically-proficient and experienced VS organization capable of contracting with the local government, 2) to stabilize the road system using VS, and 3) to empower local indigenous communities to earn an income through the provision of VS services.

- **Doan Chi Cuong, et al** report on the confusion between Vetiver grass (*Chrysopogon zizanioides* L.*)* and the local indigenous *Chrysopogon nemoralis*, which know local as Co De. As Vetiver grass is well-known for its numerous unique characteristics and environmentally friendliness. Currently, Vetiver grass is grown and widely applied in many areas around the world. In Vietnam, Vetiver is grown and used extensively since early the 1990s to prevent erosion and landslide, and effectively treating the contaminated environment. Therefore, the demand for this grass is growing. However, there are many species of vetiver and ecological distribution worldwide. In terms of external morphology, it is not easy to differentiate between the south Indian vetiver (*Chrysopogon zizanioides)* and

the local indigenous *Chrysopogon nemoralis*, which know local as Co De, especially general public.

Presently, at many areas in Quang Nam Province Co De, which has morphological characteristics similar to the Vetiver grass, is being exploited and used to prevent erosion and landslide in several projects. However, its performance and effectiveness are not high. Thus causing negative impact on the environment as well as psychological doubts about the effectiveness of vetiver.

This paper discusses the confusion between the south Indian vetiver *Chrysopogon zizanioides* and the indigenous Co De *Chrysopogon nemoralis*. Following that, some distinguishing characteristics of the two grasses will be highlighted in order to eliminate the confusion; thereby improving the efficiency and usage of vetiver grass.

- **S. Jayashree et al** reported that *Vetiveria zizanioides* Nash is a well-known medicinal plant in South India traditional medicine for the management of many diseases, but investigation concerning its pharmacological characteristics are rare. In this study, we evaluate its venom neutralizing properties against *Echis carinatus* venom in mice. Freshly collected *Vetiveria zizanioides* roots were air dried, powdered and extracted in aqueous. To study the anti-venom properties, the venom was administered intraperitoneally the mice (male) weighing between 18-25gm were randomly divided into eight (8) groups of five (5). Group 1-8 received water, plant extract, venom alone (5µg/ml; middle dose-10µg/ml; and high dose- 15µg/ml), plant extract (01 ml at four times) a respectively. After 30 minutes venom injected through i.p the extract was administered orally at a dose of 0.1ml for every 2 hours during eight hours. Later envenomation different parameters such as blood count, antioxidant enzyme activities like CAT, SOD, MDA, GPx, GSH, AST, ALP, and ALT were noted. At the end of the observation eight hours period, animals were sacrificed and dissected for adverse effects if any based on histopathology examination of their brain, heart, liver, and kidney. Our results showed that *Vetiveria zizanioides* aqueous root extract (VZRE) neutralized some biological effects of *Echis carinatus* venom (ECV). The venom increased the enzyme activities and other blood parameters. The plant extract was able to reduce these parameters in the extracted treated groups. Details of the results are discussed. From this study, it is clear that *Vetiveria zizanioides* root extract had anti-venom activity in animal model. The above result indicate that the plant extract possess potent snake venom neutralizing capacity and could potentially be used for therapeutic purpose in case of snake bite envenomation.

- **Prasert Salanla-Umpai et** al presented the works conducted by PTT, a Public Company Limited company, which first introduced vetiver utilization in 1996 along the Thai-Myanmar natural gas pipeline. Discovering its effectiveness in reforestation project, prompted PTT to expand vetiver cultivation in 2003 throughout its nationwide networks and in outside areas. In 2006, PTT jointly organized a cultivation competition with the Chaipattana Foundation, the Office of the Royal Development Projects Board, and the Land

Development Department. The project bore outstanding results in vetiver use for soil and water conservation and PTT was awarded the King of Thailand Vetiver Award.

PTT has utilized, promoted and expanded vetiver cultivation as follows:

1) Within the PTT Group's area-based and its networks.
2) The Development and Promotion of Vetiver Utilization under Royal initiative project.
3) Development of Vetiver handicrafts.
4) Development of Vetiver Network of Thailand.
5) The Application of Vetiver System and Bio-Engineering for Preventing Soil Erosion

In 2008, PTT shifted its vetiver strategy and adopted the "upstream from downstream" approach, prioritizing the promotion of vetiver handicraft creation to provide economic incentives for farmers to cultivate vetiver for conservation and financial gain. PTT has provided vetiver grass training courses to nearly 3,000 villagers from 21 communities. in design and marketing, as well as joining with the PatPat Shops of Chaipattana, selling high quality and empowering sustainable development by using vetiver as "the miracle grass".

Handicraft development has led to an increase in vetiver use in soil and water conservation too, with 2.23 million saplings, covering over 214,000 rai, planted in 2014 and supplementary incomes totaling over THB 4.39 million from handicraft sales in PatPat Shops alone.

Environmentally, vetiver cultivation rehabilitates depleted soil, making land fertile again. Socially, vetiver cultivation and the handicraft network has created unity within communities and brought communities together. Several vetiver nursery centers around Thailand have been established to provide training and spread vetiver cultivation knowledge both domestically and abroad.

PTT and the PatPat Shops of the Chaipattana Foundation have plans to further develop vetiver design as part of student curriculums, in partnership with higher educational institutes. The aim is to attract new ideas from the younger generation, help pass on local handicraft skills, and continue to protect Thai heritage and conserve the country's precious resources in accordance HM the King's Royal Initiatives; helping the roots of vetiver "grow deeper in all Thai hearts."

Certificates of Excellence

The King of Thailand Award for Dissemination and Technology Transfer

SOME HIGHLIGHTS

As presented above, this summary includes a very large numbers of significant and high quality papers, but I have singled out the following three papers to highlight the role of VST research and applications that can have global effects and will lead the Vetiver movement in the future.

1. The first to illustrate the unique role of Vetiver Phytoremediation Technology in remediating a major future problem. In the project <***Effectiveness of vetiver grass in phytostabilization and/or phytoremediation of dioxin-contaminated soil at Bien Hoa airbase, Vietnam – An overview and preliminary result***> Dr Ngo Thi Thuy Huong from the Vietnam Institute of Geosciences and Mineral Resources, Hanoi, investigated the phytoremediation technology for mitigation and/or bioremediation of soils contaminated with dioxin at low and moderate levels. The two main objectives of this project are to investigate:

- The capability of vetiver grass in **phytostabilization** of dioxin-contaminated sites, preventing its offsite contamination; and
- Its effectiveness in the **bioremediation** of the dioxin-contaminated soils.

The experimental site consist of two groups of 100 m^2 each with the initial dioxin levels in soil of about **1000 – 1800 ppt (part per trillion) TEQ**. Due to the severely eroded and extremely poor soil at the site, the first group (G1) received DECOM 1, a soil supplement promoting growth of indigenous microorganisms in the rhizosphere to ensure reasonable establishment, and the second group (G2) as a control, without supplement.

One month after planting, there was no difference in growth (plant height) and tiller number per clump between two groups. But differences in growth were observed after 6 onward between G1 (76 cm diameter and 14 tillers) and G 2 (68 cm and 10 tillers). From 6 to 12 weeks, the number of tillers increased very fast, with 14 to 26 tillers for G1 and 10 to 20 tillers for G2. As the plant mature growth of vetiver slowed down from week 12 to week 16 in terms of the number of tillers and plant height. At week 16, the circumference of G1 and G2 were 25 and 24 cm, respectively, indicating that vetiver can be established and thrive under the harsh and dioxin contaminated soil without soil supplement'

This investigation is in progress and results to date showed that only 4 months after planting vetiver grass can be used for **phytostabilization** of dioxin-contaminated sites, preventing its offsite contamination. Final results are expected in the next 13 months with three sampling of plant and soil for dioxin analyses.

Equally important is this project was approved and funded by the Ministry of Natural Resources and Environment of Vietnam (MoNRE).

The significance of this project is that dioxin contamination is not limited to herbicides, such as 245T in Agent Orange, but it is a by-product of numerous industrial chemical processes, such as fertiliser and plastic manufacturing. But due to its extremely low level (part per trillion) and very expensive to analyse, the presence of dioxin in our food chain and environment is not known generally. If the second objective of this project, namely: ***Vetiver effectiveness in the bioremediation of the dioxin-contaminated soils,*** can be achieved, that Vetiver can absorb and break down dioxin in the plant, then its role in environmental protection is immeasurable.

2. The second one to show how VST applications can be monitored globally. In a project entitled < ***Management and monitoring of vetiver grass plantation in Thailand by using vetiver grass tracking system***> Kittima Sivaarthitkul and her team from Thailand Land Development Department (LDD) have developed the Vetiver Grass Tracking System

(VGT) since 2011 to manage and monitor the database of vetiver grass plantations in various parts of Thailand. VGT is a spatial Geographic Information System (GIS) designed into 14 fields of vetiver planting data, which the 26 agencies in both government and private sectors can access, edit and retrieve all information directly via the LDD website. The vetiver grass planting data in 14 fields can be separated by location and geographic coordinates, ecotype, number of tillers, pattern and benefit of vetiver plantation including figures and video displaying the activities. As the result of vetiver plantation throughout of the country during the year 2011-2014, presently the database in VGT has a total of 5,311 records (sites).

Currently there are totally 418 million tillers planted from 2011-2014 and the number continually increases from 39 million tillers in 2011 to 133 million tillers in 2014. The Northern part of Thailand has the most number of planted tillers equal to 145 million tillers (34.75%). The level planted in the Central plain is equal to 107 million tillers (25.79%). In the North Eastern and Southern parts of Thailand there are 92 million tillers (22.08%) and 72 million tillers (17.38%) respectively. The pattern and purpose of vetiver plantations in the agricultural areas is mainly in protection of soil sediment into reservoirs (2,481 records or 60.09%), soil erosion prevention with 1,999 records (29.04%) and improvement of soil fertility and soil moisture conservation with 95 records (2.30%). LDD is the government agency that supports the vetiver tillers and technically supports the vetiver plantations to other agencies.

The VGT database shows that *Chrysopogon zizanioides* is the predominant species with 4,092 records (97.45%) planted in Thailand. In addition, the database is designed to be easily used, and is, convenient and effective for officers and the general public to access for information on vetiver grass plantation in various parts of Thailand including maps and attribute data at http://eis.ldd.go.th/vgtrep/vgtrep.asp

Most importantly, policy makers can use the VGT database as a tool to monitor and manage implementation activities and plans, to promote future vetiver use and continually advocate for the utilization of vetiver for soil and water conservation, soil improvement and environment preservation.

3. The third one to illustrate the use of native endemic vetiver species for local areas. In a project entitled <***Using Native African Species to Solve African Wastewater Challenges: An In-Depth Study of two Vetiver Grass Species*** > Effiom Oku et al in Nigeria compared the effectiveness of the native African vetiver *Chrysopogon nigritana* with the well-known and commonly used south Indian *Chrysopogon zizanioides* in treating effluents from a fertilizer blending company, quarry industry and leachate from public untreated refuse dumpsite. Results show that both *C. zizanioides* and *C. nigritana* were effective in improving the pH and removing contaminants such as BOD and COD and pH, Nitrate, Phosphate, Cyanide, Lead, Zinc, Iron, Cobalt, Cadmium, Arsenic and Manganese. However, the most significant finding is that *C. nigritana* is more effective in removing Phosphate, and *C. zizanioides* in removing Nitrate, the two key pollutants. The authors suggest that to maximize the treatment efficiency, wherever possible, both species should be used together to gain further benefit from their complimentary attributes.

It is important to point out that the native African vetiver *C. nigritana* is fertile; it can be found in a number of countries located mainly within the Niger and Zambezi River Basins Therefore its applications should best be confined to those African countries where it is known to exist. Like *C. zizanioides* it is primarily found in its natural state associated with wetlands. *Chrysopogon nemoralis* is another vetiver that is widely used in Thailand, it is endemic to South East Asia and commonly known as highland vetiver in Thailand, and it is also very widespread in Vietnam (note *C. nemoralis* has distinctly different characteristics when compared to *C. zizanioides* in that its roots are much shorter). Several papers at this Conference compare the effectiveness between *C. nemoralis* and *C. zizanioides* in various applications. The following two examples will illustrate the confusion between these two species.

1- In the paper < ***Laboratory investigation of vetiver root reinforcement for slope protection*** > Suched Likitlersuang *et al* used *C. nemoralis* in their research but they mentioned: *Vetiver grass (C. nemoralis), a perennial grass that had been promoted to help conserve the soil and runoff by the World Bank in the 1980s*. This is not correct, the World Bank only promoted the use of the non-seeded lowland Vetiver grass (*C. zizanioides*) not the seeded highland Vetiver grass (*C. nemoralis)*

2- In the paper < ***Confusion between C. nemoralis and C. zizanioides at Bo Bo Mountain in Quang Nam Province, Vietnam*** > Doan Chi Cuong et al pointed out the local Co De - ***C. nemoralis -*** which has morphological characteristics similar to *C. zizanioides*, is being exploited and used for erosion control and landslide prevention in several projects. This results in failure and has caused negative impact on the environment as well as psychological doubts about the effectiveness of VST.

Therefore vetiver species have to be properly identified and correctly established at the location of application so that the effectiveness of VST is not affected.

CONCLUSION AND RECOMMENDATION

Vetiver grass, *Chrysopogon zizanioides,* is the most researched non-food and non-industrial plant to date. While it has become well established and proven in bioengineering and agriculture, its role in environmental protection needs <u>further research and development</u> to meet increasing demands created by expanding climate change, population, and pollution challenges.

The following areas need special attention:

(1) Water availability, its quality and reuse, should have high priority in future vetiver related research.
(2) The original application of VS was for on farm soil and water conservation, progress has been slow, and great focus and effort should be given for this use.
(3) Development and identification of special vetiver characteristics that may help to distinguish between species and cultivars, including genotypes that can adapt to colder climates, should be important and would help accelerate a wider and faster application of the technology.

(4) A better understanding of vetiver related technology transfer mechanism, including training of potential users, would enhance the use of VS as a technology providing for sustainable development.
(5) Expansion of monitoring and evaluation of vetiver applications would strengthen the credibility of the technology and would provide potential users with a greater degree of confidence in its adoption.
(6) VS needs to be presented as a critical technology that can be used across sectors by communities to resolve a number of climate change issues without having to resort to external funding or assistance thus enabling communities to sustain and improve their quality of life through betterment of their environment.