TRAINING MANUAL

THE VETIVER SYSTEM

By Robinson Vanoh

For The Vetiver Network International
In cooperation with
The Ministry of Waterways and Environment
Project Funded by GEF/UNDP through Fiji Ridge To Reef

The Vetiver Network International

Table of Contents

About this Publication:

The Manual of the International Training Course on the Vetiver System was first edited by Dr Narong Chomchalow, who is the Coordinator of the Pacific Rim Vetiver Network and published by the Office of the Royal Development Projects Board, Bangkok, Thailand in December 2000.

This publication is the second edition of the publication and is edited by Robinson Vanoh and Dr. Paul Truong from The Vetiver Network International. This manual re-titled “Training Manual – Vetiver System” was edited to be used as a Training Manual for training of Technical and Field Officers from the Ministry of Waterways and Environment and to be conducted in Fiji in February/March 2020.

The recommendation practices or technologies in this manual are based on research and best information available so far.

FOREWORD

This is a project initiative by the Ministry of Waterways and Environment Fiji, with financial support from the Green Environment Fund (GEF/UNDP) through the Fiji Ridge to Reef (R2R). The Training Course on the Vetiver System is scheduled to be held in Labasa (25-27 February) and in Suva (3-4 March) 2020 by the Ministry of Waterways and Environment. Those in attendance will be team leaders from respective Departments and also selected community leaders who will be involved in the implementation program.

This training will be facilitated by Dr. Paul Truong (Senior Technical Director Asia Pacific) and Robinson Vanoh (Associate Director South Pacific) through PowerPoint presentations with the idea to help the trainees to learn as much from the facilitators. Training will be followed with an actual field day where trainees will implement what they have learned on the first day. By the end of the training course, each trainee will receive soft copies on thumb drive all PowerPoint presentations, videos and the Training Manual as a gift from the course presenters.

The Editor, who is also the Course Director, take full responsibility in the contents of this Manual, of which some mistakes may still be present, either typographical errors, English grammar, or scientific validity, as well as the different format of all the papers contained herein.

Special thanks are due to Dr. Mahendra Reddy (Minister for Waterways and Environment) as the project initiator and this has been his brainchild in re-introducing vetiver grass. Also to Mr Amit Singh (Director Policy, Planning and Implementation) for all the support accorded in facilitating and making this training possible, Mrs Beverly Sadole (National Manager Fiji R2R) for facilitating funding support, and all the staff from the Ministry of Waterways and Environment who have worked so hard beyond the call of their duties to make this course one of the most successful and enjoyable ones.

My gratitude and special word of thankyou to the Green Environmental Fund (GEF/UNDP) for making it possible with funding support to facilitate this training program. Without their funding support, this important training would not have being made possible.

The Editor is very thankful and grateful to Sir Richard Grimshaw, Mr Jim Smyle, Dr. Paul Truong, Dr Dale Rachmeler and Mr Paul Zuckerman who has been very supportive and gave valuable suggestions, technical advice and guidance during my advocating in the South Pacific leading into the training. In particular, I am indebted to Dr Narong Chomchalow for the preparation of the first Manual.

This manual should be of some value to those people who are interested in the Vetiver System and in a long way, will help to promote the re-introduction of VS in Fiji as a Green Solution for Sustainable Development.

Robinson Vanoh
Editor and Course Facilitator
The Vetiver Network International

1. INTRODUCTION

1.1 ABOUT THIS TRAINING

The Ministry of Waterways and Environment Fiji decided to introduce Vetiver System to deal with soil erosion and is embarking on promoting the wide spread use and utilization of vetiver for stabilization of all its vulnerable riverbanks in Fiji. Riverbank erosion is becoming more prevalent, it is becoming a threat to communities and livelihoods of people depending on the land along these streams. The Government is implementing a program on an integrated approach using Green Technologies for riverbank stabilization, coastal and environmental protection.

Frequency of flooding has increased over the years due to the reduced conveyance capacity of the rivers from siltation which is causing extensive damage to farms, crops and properties. Over the last 15 years, the riverbanks have completely shifted and are causing havoc. The Fiji Ridge to Reef (R2R), with funding support from the Green Environmental Fund (GEF/UNDP) will be funding this project which is an initiative of the Ministry of Waterways and Environment.

The funds will be appropriated and used to fund three main activities: Awareness, Capacity Building and Knowledge Management which also includes monitoring of current planting to ensure of its successful growth. Technical in-house presentation workshops will be held for all team leaders from various responsible departments which will also include selected community representatives who will be involved and be contributing towards the implementation of the project.

During the community training and awareness – short documentary videos will be created to document the project phase. The Ministry, in cooperation with the Land Use Division from the Ministry of Environment, its various member agencies, is making preparation for the training course to be held in Fiji in February/March 2020. The main objective of this international training course is that after the training, the trainees will become familiar with the Vetiver Systems and the various technologies employed, appreciate what is being done in research, experimentation and application, and have concepts on how to implement the technology in their own environment.

1.2 WHAT IS THE VETIVER SYSTEM?

1.2.1 Definition of the Vetiver System

The Vetiver System (VS), originally known as the Vetiver Grass Technology (VGT), is a low-cost, simple technology employing live vetiver plant for soil and water conservation and environmental protection. VS are a very practical, inexpensive, low maintenance and very effective means of soil erosion and sediment control, water conservation, and land stabilization and rehabilitation. Being vegetative, it is also environmentally friendly.

The Vetiver System is an organic glue to support sustainable development at all scales as shown below.

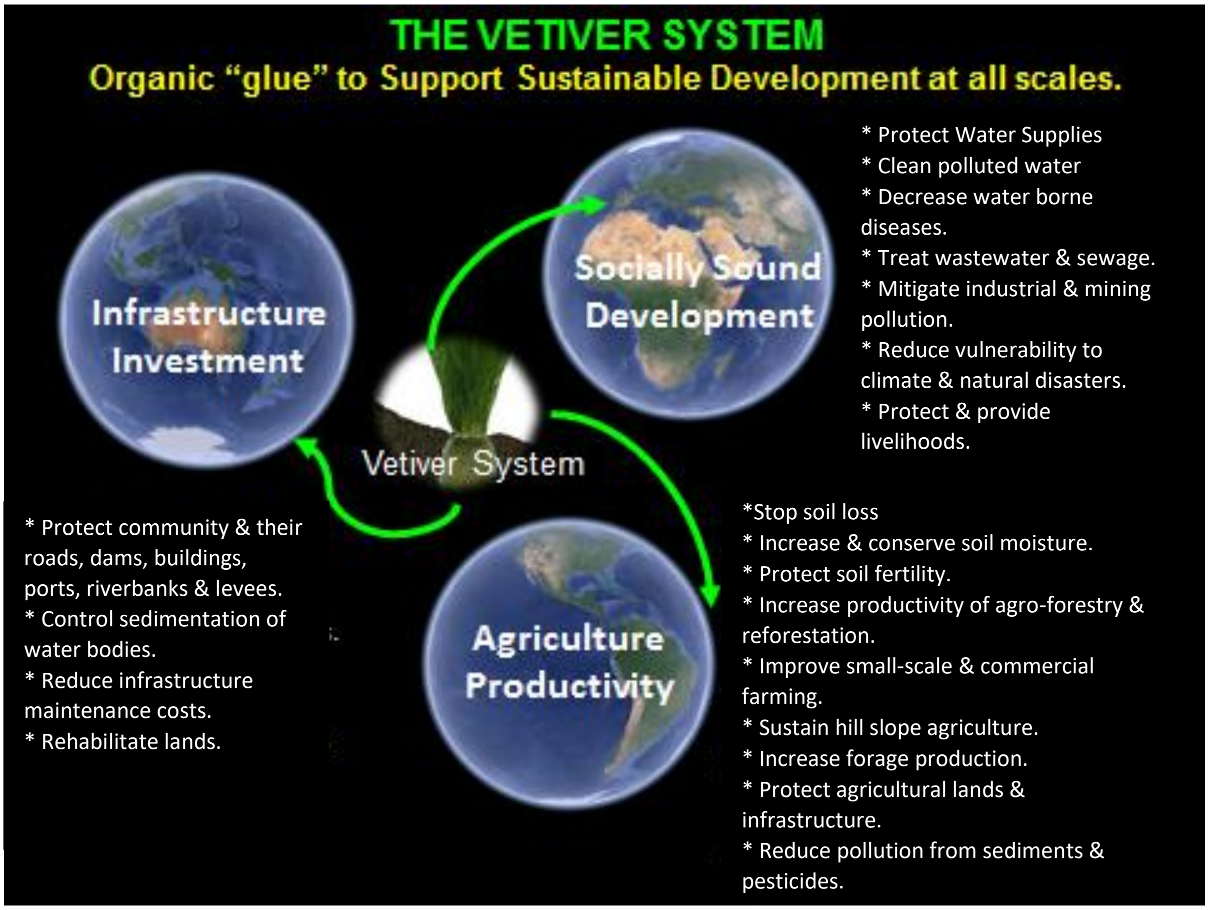


Diagram 1: Illustration of the Vetiver System.

1.2.2 Genesis of Vetiver

The plant vetiver belongs to the same group of grass family of rice, maize, sorghum, sugarcane, and lemongrass. It got its generic name Vetiveria, from its Tamil name "vetiver" which means root that is dug up. Zizanioides means by "the riverside." The fact is that the plant is commonly found along the waterways. Its name was later reclassified as Chrysopogon zizanioides (Madhu and Haridas 2011). Vetiver has been known to India since ancient times. It has been considered as a high-class perfume, and copper plate inscriptions list the perfume as one of the articles used by royalty. Two species of Vetiveria are found in India, of which V. zizanioides is the common source of the well-known oil of vetiver, which is used in medicine and in perfumery. The species of Vetiver System (Chrysopogon zizanioides) originates in the state of Tamil Nadu, South India, which is now being promoted in nearly 100 countries. It is sterile and non-invasive and has to be propagated by clump subdivision.

Vetiver grass was first introduced to Fiji from India probably late in the 1800's to provide thatching material for houses and it is still being used for roofing and walls. Although it was commonly used to stabilize embankments, terraces and to delineate farm boundaries, its application as a soil conservation measure as we know today was first developed early in the 1950's by John Greenfield to control soil erosion on CSR (Colonial Sugar Refinery) sugar estates. As thus, John Greenfield is known as the "father" of VS.

On Viti Levu, which is the main island, the Fijian sugar industry concentrated along the west coast where suitable low slope land is very limited. As the sugar industry expanded, the main sugar production company, CSR was faced with a very severe soil erosion problem on sloping lands, particularly on the north western area around Rakiraki, where the land is very steep and rainfall is often of very high intensity. That I where it was first planted and it still stands today.

1.2.3 Applications and Uses of Vetiver

The main components of the Vetiver System are the applications of live vetiver plant in agricultural (details in Chapter 6) and non-agricultural applications (details in Chapter 7), and uses of dry vetiver plant which are by-products of vetiver grown for soil and water conservation in handicrafts, roof thatch, mushroom growing, animal fodder and feed stuff, industrial products, herbals, etc. (details in Chapter 8, also in Chart 1).

1.3 HOW DOES VETIVER WORK?

When planted in row in close space, vetiver plant will form a hedge, a living porous barrier which slows and spreads runoff water and traps sediment. As the water flow is slowed down, its erosive power is reduced and at the same time allows more time for water to infiltrate to the soil, and any eroded material is trapped by the hedges. Therefore, an effective hedge will reduce soil erosion, conserve soil moisture, and trap sediment on site. This is in sharp contrast with the contour terrace/waterway system which runoff water is collected by the terraces and diverted as quickly as possible from the field to reduce its erosive potential. All this runoff water is collected and concentrated in the waterways where most erosion occurs, particularly on sloping lands where this water is lost from the field. With the VS, not only this water is conserved but no land is wasted on the troublesome waterways. Although most hedges can do that , vetiver plant, due to its extraordinary and unique morphological and physiological characteristics (see details in Chapter 4) can do it better than all other systems tested .

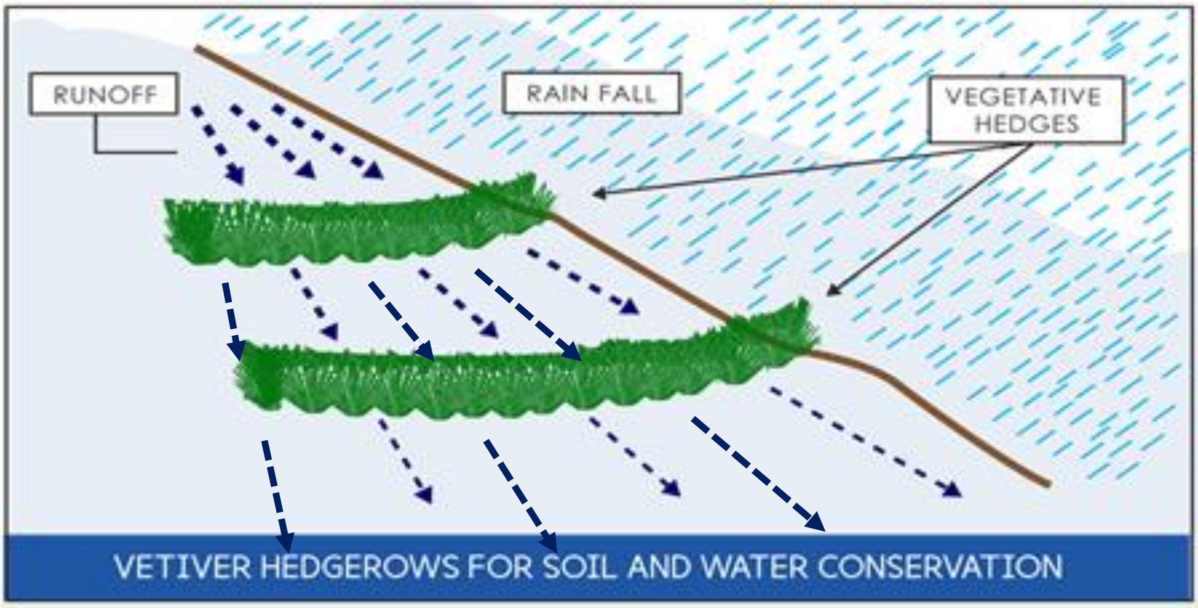


Diagram 2: Vegetative hedgerow (Illustration from VEEP brochure)

2. THE PERSPECTIVES

2.1 VETIVER: THE MIRACLE GRASS

2.1.1 Unique Root System

With its extensive fibrous root system which penetrates deep down into the soil at great depth (2m in the initial year then 5+ as the soil builds up). Its roots were found to break through hardpan as thick as 15cm. They were also found to have 'innate' power to penetrate a fairly thick layer of asphatic concrete. On slopes underlain with weathered rock, boulders or relatively hard layer, its penetrating roots will provide anchorage by root tendon action. Its action is comparable to a nail which could penetrate deep layers of soils whose texture may be quite hard, and at the same time it has the ability to hold soil particles together through its extensive fibrous roots, thus avoiding soil erosion due to wind and water, making it well known among road engineers as the 'Living Nail'.

Picture 1a & 1b : Fibrous rooting structures of Vetiver (right - potted root)

2.1.2 Unique Tussocks when Grown as Hedgerows

The act of its clumps which are able to slow down the rapid movement of water and wind is really amazing. The direct benefits of this 'living wall' or 'living barrier' are: (i) increasing organic matter and moisture in front of the hedgerows, and (ii) acting as a sieve, and not allowing any debris to pass through but to accumulate in front of the hedgerow.

Picture 2: Two months old Vetiver Hedgerow (Papua New Guinea)

2.1.3 Unique Living Dam

The act of both the roots and clumps as a 'living dam' is also amazing. Their direct benefits are as follows: (i) adhere soil particles thus reducing soil erosion, (ii) increase the amount of organic matter collected in front of the hedgerow, (iii) increase moisture content in front of the hedgerow as the result of accumulation of organic matter and water, (iv) filter out toxic substances brought in by water and, after being absorbed in the plant tissues (see its tolerance later), these will slowly disintegrated, while clear and clean water is able to pass through this living dam.

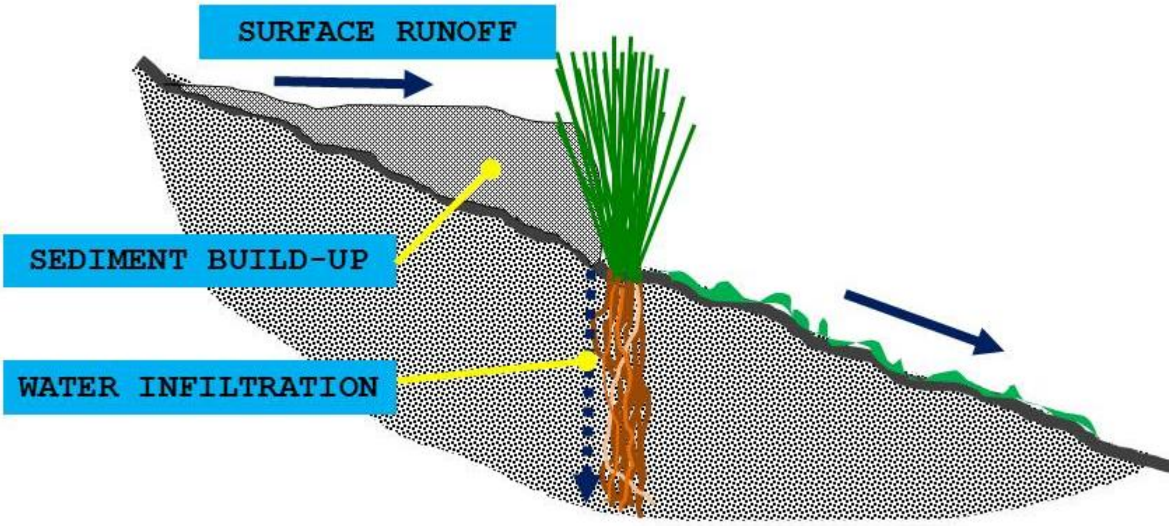


Diagram 3: Illustrations of Sediment build up and water infiltration

2.1.4 Tolerance to a Wide Range of Environmental Stresses

The Vetiver System (VS) was first developed for Soil and Water Conservation on the farmlands. While this application still plays a vital role in agricultural lands, vetiver's unique morphological, physiological and ecological characteristics, including its tolerance to highly adverse conditions, has played a key role in the area of environmental protection and land rehabilitation. These include tolerance to the following adverse conditions: (i) acidity, manganese and aluminium, (ii) salinity and sodicity, and (iii) heavy metals like arsenic, cadmium, copper, chromium, lead, mercury, nickel, selenium and zinc.

2.1.5 Ability to Absorb Toxic Substances

Not only vetiver can tolerate adverse soil conditions, but it can absorb toxic substances like pollutants, pesticides, and heavy metals into its biomass (mostly in its extensive roots), thereby diluting such toxic substances in the soils and water, making them safer in agricultural and non-agricultural activities. One such activity is the use of vetiver to purify eutrophicated water in the lake, leachate from garbage landfill, etc. It can also be used to absorb heavy metals from quarry, and such valuable metals can be recycled by extraction from the vetiver biomass.

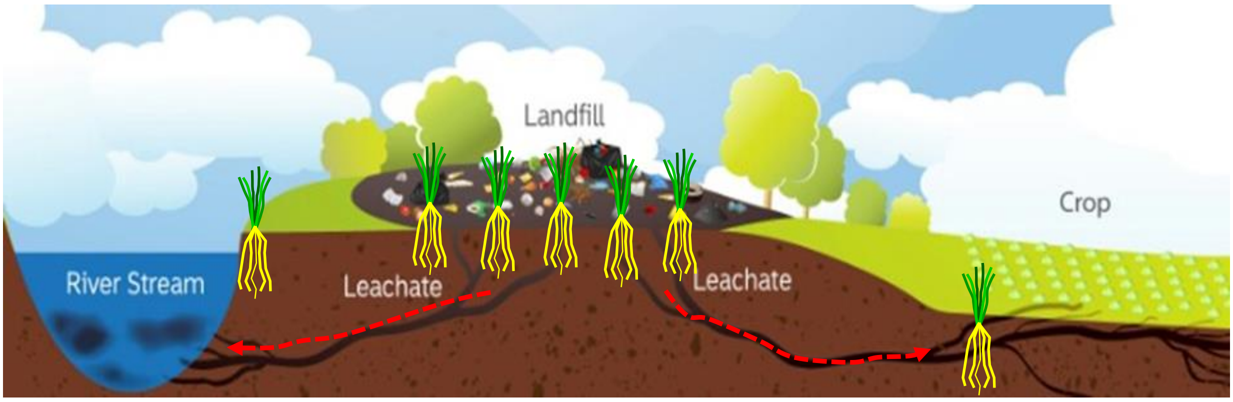


Diagram 4: Flow of leachates from domestic landfill into the environment

2.2. THE VETIVER PLANT

2.2.1 Genetic and Taxonomic Features

Vetiver grass (*Chrysopogon zizanioides* L.) belongs to the same grass family as maize, sorghum, sugarcane, and lemon grass (Table 1 and Figure 1). It is native to tropical and subtropical India and is one of the most widely distributed Vetiver grass species in South and Southeast Asia.

The name Vetiver is originally derived from Tamil (South India) and originally classified as *Vetiveria.* Since *Vetiveria* and *Chrysopogon* are not separable based on Random Amplified Polymorphic DNAs (RAPDs), this led to the merging of the genera *Vetiveria* and *Chrysopogon*. Hence *Vetiveria zizanioides* (L. Nash) is now known as *Chrysopogon zizanioides* (L Roberty), with chromosome base number, x=5 and 10, 2n= 20 and 40.

Besides *Chrysopogon zizanioides* L., there were numerous accessions of *Vetiveria zizanioides* (L. Nash) and other Vetiver species such as *Chrysopogon fulvus* (Spreng.), *C. gryllus*, *Sorghum bicolor* (L.) and *S. halepense* (L.).

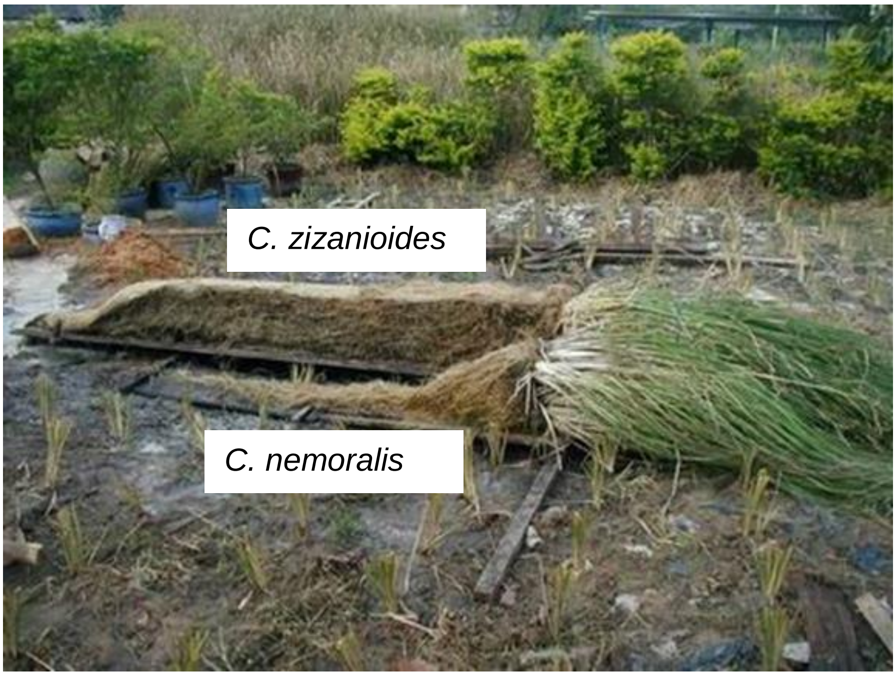
Eleven species of Vetiver are recorded, with distribution in tropical Asia (including Pacific Islands and Australia) and Africa. Two species, *Chrysopogon zizanioides* (lowland Vetiver - wide distribution in tropical Asia), and *C. nemoralis* (upland Vetiver restricted distribution in mainland Southeast Asia) are used in the Vetiver System (i.e. use and utilization). The former has also been used in essential oil production and as traditional medicine. While *Chrysopogon zizanioides* is sterile, it flowers but set no seeds*, C. nemoralis* is fertile, it set viable seeds

2.2.2 Ecology

The two species, low land and upland Vetivers are able to grow in various types of soils from sea level to 800 masl. Both species need bright sun with high temperatures, but cannot stand low temperatures. It is a tropical grass which can well adapt to different environmental conditions. In PNG, Solomon Islands, Vanuatu and Fiji, *Chrysopogon zizanioides* can be found growing in a wide range of areas, from the highlands to the coastal areas. It appears with dense clumps and is fast growing through tillering. When planted on contour line on slopes, the clump which stands above the ground will produce tillers, forming a green hedge. This makes it capable of trapping crop residues and silts eroded by runoff, leading to natural earth terrace formation. With a deep, dense root system spreading vertically, rather than horizontally, vetiver can be tolerantly grown under adverse conditions.

2.2.3 Genetics

Seed sterility is obviously genetically controlled although its mechanism has not yet been confirmed through genetic study. While the seeded genotype of *C. zizanioides* is only used in northern India for essential oil production, not from cultivation but from wild swamps, the southern and sterile genotype is the main vetiver cultivated for essential oil production and this is the genotype that is being used around the world for soil and water conservation and land stabilization purposes because of its unique and desirable characteristics mentioned above. The wild type of *C. nemoralis* is fertile and set viable seeds, *hence it should not be introduced to new environment* because of its weed and invasive potential. In addition *C. nemoralis* has a very shallow root system and low biomass production as compared with *C. zizanioides*



Picture 3: Two year old Vetiver roots in Vietnam

2.2.4 Biotechnology

Through the use of new technology known as biotechnology, vetiver has been subjected to two kinds of studies, namely tissue culture method of propagation and

DNA finger printing to determine their variation. The first approach is to have rapid mass propagation using the explants derived from the young shoots of young inflorescence, and grow them in aseptic condition to produce cell mass known as callus, which is then allowed to multiply until enough is produced. With the change of nutrient, callus differentiates of into root and shoot of the plantlet, which is still in aseptic condition until attaining a good size before it is transferred to be grown in the nursery.

2.3 THE VETIVER SYSTEM

2.3.1 Applications and Uses of Vetiver

The main components of the vetiver system are the uses of live vetiver plant in agricultural (details in Chapter 6) and non-agricultural applications (details in Chapter 7), and uses of dry shoot and root of vetiver plant which are by-products of vetiver grown for soil and water conservation in handicrafts, roof thatch, mushroom growing, animal fodder and feed stuff, industrial products, herbals, etc. (details in Chapter 8). (See also Chart 1 on following page)

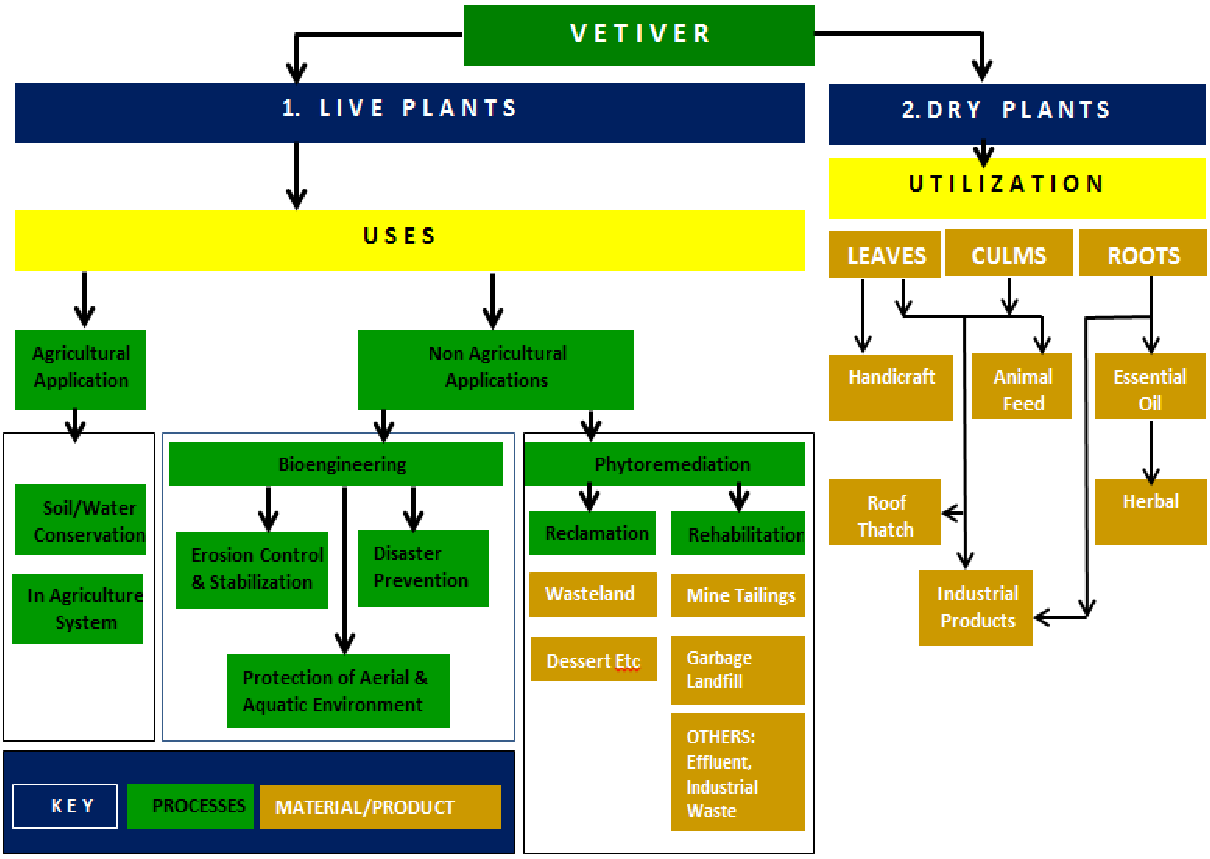


Chart 1: Uses and Utilization of Vetiver

2.3.1.1 Applications of Vetiver

Involves any direct exploitation of live vetiver plant such as for soil and water conservation, slope stabilization, erosion control, environmental protection, etc. without having to change or process the vetiver plant into finished or semifinished products. Application of vetiver in agricultural and non-agricultural systems was first developed by the World Bank for soil and water conservation in the 1980s. It is one of the most effective and low cost natural methods of environmental protection deriving from its tolerance to adverse soil conditions and heavy metal toxicities, and phytoremediation, as well as in erosion protection and slope stabilization.

2.3.1.2 Uses of Vetiver

Involves some kinds of processing of dead vetiver plants, including cut leaves, culms, roots, roots after essential oil extraction, etc. in the making roof thatch, for essential oil extraction, as a medium for mushroom growing, as raw material for handicraft making, as raw material for processing into industrial products (e.g. biodegradable nursery blocks or pots, construction materials, etc.). It does not include, however, the utilization of roots for essential oil extraction, since this requires the harvest of root mass which should be left in the ground to perform its main function in soil and water conservation.

But when the roots are harvested for essential oil production, the root biomass can also be used for handicraft making as in India and Indonesia or biofuel in the Dominican Republic.

2.3.2 Agricultural Applications

Traditionally, vetiver has been used for Soil and Water Conservation in India for centuries before the Vetiver System has been popularized in recent years. The basis of soil erosion and acceptance of soil conservation measures will first be discussed in Section 6.1 in order to help the trainees to understand the principle of soil erosion and its consequences. The use of vetiver in soil and water conservation, including soil erosion and sediment control on sloping land and flood plain, flood erosion control and slope stabilization, etc., will then be discussed in Section 6.2, followed by the works done by the Department of Land Development in Northern Thailand on the use of vetiver in Soil and Water Conservation in Agricultural lands (Section 6.3).

The techniques of application of Vetiver Hedgerows on farm drains will be discussed in Section 6.4 with demonstration to be held at a selected site during the study tour. Other benefits of growing vetiver like Soil Moisture Conservation, Watershed and Catchment Management, Biological Pest Control, Phytoremedial Application, and trapping of agrochemical and nutrients will be discussed in Section 6.5.

2.3.3 Non-Agricultural Applications

It is undeniable that human activities are the main source of changes in the world geography and environment. Explicit examples of such acts include the destruction of mountains to build highways and roads, drilling of mountains for mining, construction of dams across the rivers to build reservoirs, or the destruction of forest resources.

Picture 4: Matokana village access road (Fiji) – Picture by FRA

Besides these, other causes include chemical changes in the atmospheres as a result of emission of gas or certain types of chemical substances, earthquakes, and landslide and land subsidence, extinction of wild animal and plant species, as well as waves of extreme heat or drought which have occurred in several parts of the world including Australia in 2019. Undesirable and critical changes to the environment caused by man are now having impacts on human lives beyond control. Worst of all, one cannot anticipate the possible disastrous outcomes of this ongoing situation. Different methods including reliance of heavy machinery and cultivation of various crops have been attempted to resolve and prevent the problem. The use of vetiver in non-agricultural applications can be categorized as follows:

2.3.3.1 Bioengineering (prevention mechanism)

Bioengineering is defined as the use of organisms, mainly plants, on its own in integration with civil engineering works, to address the problems of erosion and slope stabilization. In this regard, vetiver can be employed in the followings:

Erosion Control and Slope Stabilization

- Stabilizing Soil and Slope
- Trapping sediment
- Reducing runoff velocities
- Diverting flow
- Enhancing infiltration
- Protecting hard structure/soil interfaces
- Trapping agrochemicals and nutrients

Picture 5: Slope stabilization in 2016 (Gizo, Solomon Islands)

Erosion control and other stabilization

- Embankment stabilization
- Gully stabilization
- Catchment stabilization

Picture 6: Water catchment stabilization

Protection of aerial environment

- Control of dust pollution
- Control of greenhouse gas

2.3.3.2 Phytoremediation (cu ring mechanism)

The use of plants to clean up contaminated or poluted soils and water. Vetiver has been found to be extraordinarily efficient in the followings:

Reclamation is the process of using certain methods, mechanical or biological, to reclaim degraded soils. The term is sometimes used synonymously with rehabilitation by many authors. In the present paper and in this training course, reclamation is used to make the degraded soils, which have been caused by natural phenomena or processes, suitable for crop cultivation. Such naturally-caused deteriorated soils include:

- Saline soil
- Acid sulphate soil
- Skeletal soil
- Sodic soil
- Sandy soil
- Mangrove soil
- Shallow soil
- Steep-slope land

Rehabilitation is the process of using certain therapy, mechanical or biological, to rehabilitate contaminated soils or water caused by human intervention. Thus, distinction can be made between reclamation and rehabilitation by the causes of such soils; if natural then the term reclamation is used; if man-made, then the term rehabilitation is used. However, sometimes, the term rehabilitation is used for such natural phenomena as "rehabilitation of cyclone-hit areas". Areas of land or water caused by human intervention which can be rehabilitated include:

- Garbage landfills (where leachate is to be purified or disposed)
- Mine tailings
- Industrial waste dumping areas with heavy metal contamination
- Effluent from aseptic tanks and piggeries, cattle and poultry farmers.
- Polluted water Effluent from aquaculture
- Algal bloom in water body
- Heavy metals in industrial effluent disposal

Picture 7: Sewage effluent treatment in 2019 (Goroka, Papua New Guinea)

2.3.3.3 Disaster prevention, mitigation and reclamation

A special phenomenon caused by natural phenomena such as storm, flood, runoff, etc. which result in disasters such as landslides, mudslides, collapse of infrastructures, dams, embankments, etc. Although can be discussed under bioengineering (as a prevention mechanism of disaster) and phytoremediation (as a curing mechanism of disaster), it is best to describe in a separate topic, which include:

- Storm mitigation
- Landslide prevention and mitigation
- Flood prevention and mitigation
- Stabilization of sand dunes
- Beach erosion

3. BASIC KNOWLEDGE ON THE VETIVER PLANT

3.1 ORIGIN AND DISTRIBUTION

As mentioned in 2.2.6, Genetic and Taxonomic Features. Vetiver belongs to the same group of the grass family[1/] as maize, sorghum, sugarcane, and lemongrass. Its botanic name is, *Vetiveria zizanioides* (Linn.) Nash, has had a checked history. At least 11 other names in four different genera have been employed in the past. Its generic name, *Vetiveria,* deriving from "vetiver," a Tamil word, meaning "root that is dug up", was given first by the great Swedish taxonomist, Carolus Linneaus, in 1771. Its specific epithet, *zizanioides,* means "by the riverside", reflects the fact that the plant is commonly found along the waterways.

3.1.1 Origin

The exact location of its origin is not precisely known. Most botanists concluded that it is native to northern India; some believed that it is native around Bombay. However, for all practical purposes, the wild plant inhabits the tropical and subtropical plains throughout northern India, Bangladesh, and Myanmar.

3.1.2 Natural Habitat

For a plant that grows so well on hillsides, vetiver's natural habitat may seem strange. It grows wild in low, damp sites such as swamps and bogs.

3.2 Botany of Vetiver

It is important to realize that vetiver are of two types; a crucial point, because only one of them is suitable for use around the world. If the wrong one is planted, it may spread and produce problems for farmers. These two types are:

- A wild type from North India. This is the original undomesticated species. It flowers regularly, sets fertile seed, and is known as a "colonizer". Its rooting tends to be shallow, especially in the damp ground that it seems to prefer. If get loose to other areas, it might become a weed.
- A "domesticated" type from South India. This is the vetiver that has existed under cultivation for centuries and is widely distributed throughout the tropics. It is probably a selection from the wild type. It flowers but set no seeds therefore non-spreading and not invasive. Hence must be reproduced by vegetative propagation. It is the only safe type to use for VS.

It is not easy to differentiate between the two types morphologically. Over the years, Indian scientists have tried to identify distinguishing features. These include differences in:

Stems: The South Indian type is said to have a thicker stem.

[1/] *The actual family tree: Family Graminae (Poaceae), Subfamily Panicoideae (Andropogonidae), Tribe Andropogoneae, Subtribe_Sorghinae (BOSTID 1993)*

Roots: The South India type is said to have roots with less branching.

Leaves: The south India type apparently possesses wider leaves (1.1 cm vs 0.7 cm, on average)[2/]

Oil content: The South India type has higher oil content and a higher yield of roots.

Physical properties: Oil from the wild roots of North India is said to be highly laevorotatory (rotates the plane of polarized light to the left), whereas that from the cultivated roots from South India is dextrorotatory (rotates polarized light to the right).

Scent: The oil from the two types differ in aroma and volatile ingredients.

Perfumery value: The oil from the North India types fetches higher value in the perfume industry

3.2.1 Taxonomy

Vetiver is a common name of the grass in the genus *Vetiveria* which consists of 11 species widely distributed in tropical regions of Asia, Africa, Pacific Islands, and Australia. These are:

Species	Distribution
C. elongata (R.Br.) Stapf ex C.E.	Papua New Guinea, Australia
C. festucoides (Presl.) Ohwi	Japan
C. filipes C.E. Hubbard	Papua New Guinea, Aust (QLD)
C. fulvibarbis Stapf	Central and East Africa
C. intermedia S.T. Blake	Australia (Queensland)
C. lawsonii (Hook.f) Blatt. Et McCann	India
C. nemoralis (Balansa) A. Camus	Southeast Asia
C. nigritana Stapf	Central and East Africa
C. pauciflora S.T. Blake	Australia (Queensland)
C. rigida B.K. Simon	Australia (Queensland)
C. zizanioides Nash	Central and S/Et Asia

All of these 11 species are coarse perennial grasses that are found in the tropics of the Old World which belong to the tribe Andropogoneae, only Chrysopogon zizanioides has proven ideal for all VS applications mentioned above.

3.2.2 Species and Ecotypes of Vetiver Used in Vetiver System

Among 11 species of *Vetiveria,* only two are used in the vetiver system, namely *V. zizanioides* and *V. nemoralis.* The former has global distribution throughout the tropical subtropical regions while the distribution of the latter is restricted to mainland Southeast Asia from Thailand, Lao PDR, Cambodia and Vietnam. Both species are naturally grown in a wide range of natural conditions, from the lowlands to the highlands, with the altitude from close to sea level to as high as 800 m.asl. A third species, *V.nigritana,* is native to southern and western Africa and its application is mainly restricted to the subcontinent. This species is a seeded variety; hence its application should be restricted to its homeland.

Vetiver is a tropical grass which can well adapt to different environmental conditions. In Fiji, this grass can be found growing in a wide range of areas, from highlands to lowlands. The dominant vetiver grass species grown in Fiji is C. *zizanioides*. It appears with dense clumps and is fast growing through tillering. The clump's diameter is about 30 cm with a height of 50-150 cm. The narrow, erect, and rather stiff leaf is about 75 cm long and 8 mm wide.

When planted on the contour lines of slopes, the clump, which is raised above ground level, will produce tillers, forming a green hedge. This makes it capable of trapping crop residues and silts eroded by runoff, leading to natural earth terrace formation. With a deep, dense root system spreading vertically, rather than horizontally, vetiver can be tolerantly grown under adverse conditions. The roots densely bind together like an underground curtain or wall, enabling it to retain water and moisture (Nanakorn *et al*. 2000).

Horizontal expansion of the vetiver root system being limited up to only **50 cm**, it imposes no obstacle to the nearby plants, and is particularly considered being an effective measure for soil and water conservation. Vetiver hedgerows help retain soil moisture and surface soil and, at the same time, are suitable for combined cultivation along with economic crops. Growing vetiver grass is a simple and cost-effective method that has proved to be the most practical alternative in strengthening and sustaining the farming system in rain fed areas. Also, it can be adapted well to other areas for various natural resource and environmental preservation and conservation, such as along the banks of irrigation canals, reservoirs or ponds, along the roadsides and the approach of a bridge, as well as in forest areas (Nanakorn *et al*. 2000).

3.3 WHAT ARE THE USES OF VETIVER BIOMASS?

Two main parts of vetiver plant are being made use of, namely shoots and roots. In a young plant, the former is made up of only leaves, in mature pre-flowering plants it comprises of leaves and culms – the solid stems of future flower heads. The latter part, the root, is underground.

3.3.1 Culm/Leaf

The above ground portion of the vetiver plant - shoot - comprises of culm and leaves have been used in various ways, viz.:

- Hedgerow for Soil and Moisture Conservation
- Roof thatching
- Biofuel (Biomass, Briquettes for cooking, Ethanol)
- Handicrafts for Home and Market

- Livestock feed, mulch and Soil Reconditioning
- As planting material for mushroom culture and for making compost

Picture 8-10: Mature plant with flower heads and shoots of young plants

3.3.2 Roots

The extensive fibrous roots of vetiver are very useful in both soil and water conservation and other utilization of the essential oils and other components. These are:

- Soil Stabilization, erosion control and groundwater recharge
- Remove Nitrates, Phosphates, heavy metals and other contaminants
- Decomposed as organic matters, thus making the soil friable
- Carbon Sequestering
- Making screens, blinds, fans, handbags, etc.
- Making herbs and skin care substances
- Essential oil and craft production for market
- As insect and rodent repellents others (Nanakorn *et al*. 2000).

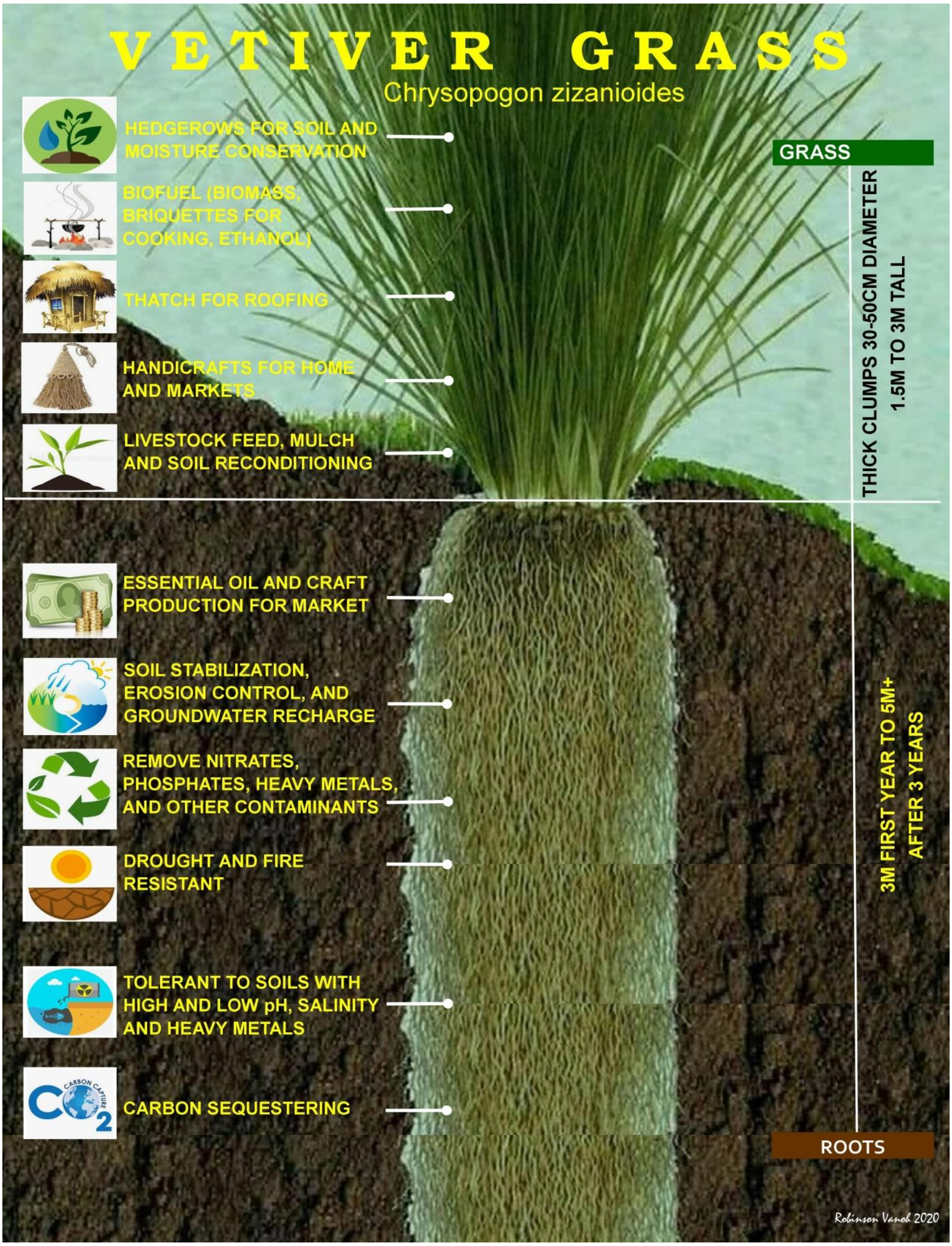


Diagram 5: The uses of Vetiver

3.4 Where can Vetiver be found as a Source of Planting Material?

Vetiver can be found approximately between the latitudes 30^o North and South, it also survives as far as 32^o South in Victoria, Australia. In most areas where there is a permanent water body, be it stream, lake, or swamp; it survives as a climax plant (Greenfield 1988).

In Fiji, it can be easily found growing mainly in sugarcane farms where they were initially introduced to in the early 1950s.

3.5 Can Vetiver Grass become a Serious Weed?

There are voices of concern that vetiver grass may become a serious weed like cogon grass *(Imperata cylindrica)*, Burmese grass *(Pennisetum polystachyon)*, or giant mimosa *(Mimosa pigra),* when introduced into other areas. Generally, vetiver propagates by producing new shoots from the main stem just above soil surface, and by branching at the joint of a mature culm that start to have inflorescence.

Most spikelets are not subject to fertilization and the seeds, which are rarely produced, are very thin, and have a short dormancy period. This allows it limited opportunity to germinate and spread like weed. However, farmers can control and eliminate these seedlings of vetiver grass easily by digging them out or by ploughing. It never appears that vetiver becomes weed in areas where it has been introduced (Na nakorn *et al.* 2000).

The Pacific Island Ecosystems at Risk (PIER) Review, which assessed the weed potential of introducing new plants to the region, considered +12 value is a low risk weed potential, the value for vetiver is - 8

Vetiver was first introduced into Fiji in the 1950's to be used in the sugarcane farms. It has been in Fiji for the last 70+ years and it has not been a treat as a serious weed. Some patches of vetiver can be seen where they were planted years back are there on the same spot without spreading, apart from been transplanted out by farmers.

4. SPECIAL FEATURES OF VETIVER

4.1 Morphological Characteristics

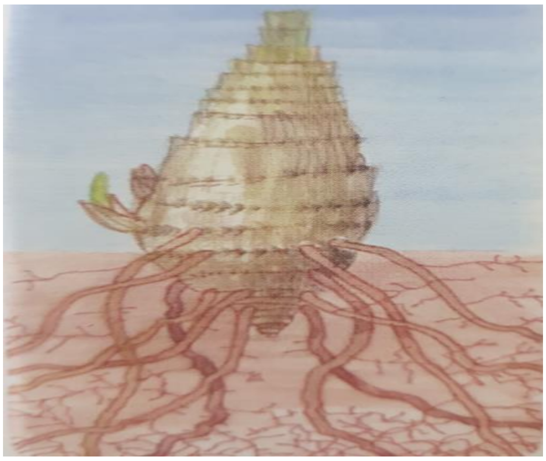
In its general aspect, a vetiver plant looks like a big, coarse clump grass, not very different from pampas grass, citronella grass, or lemongrass. It can, however, grow to be very tall. Under favourable conditions, the erect stems (culms) can reach heights of 2- 3 meters.

For purposes of erosion control, vetiver has a number of singular architectural and anatomical features:

- ***Habit:*** The plant has an erect habit and keeps its leaves up off the ground. This seems to be important in allowing the hedge to close up tight, and it also allows crops to be grown next to the plant.
- ***Resistance to Toppling:*** Unlike many grasses, vetiver is "bottom heavy." It shows no tendency to fall over (lodge), despite its very tall culms.
- ***Strength:*** The woody and inter-folded structures of the culms and leaf bases are extremely strong.
- ***Year-Round Performance:*** Although vetiver goes dormant during winter months or dry seasons, its stems and leaves stay stiff and firmly attached to the crown. This means that the plant continues stopping soil, even in the off-seasons or (at least for some months) after death.
- ***Self-Rising Ability:*** As silt builds up behind a vetiver plant, rooting from buried nodes enable it to rise to match the new level of the soil surface. The hedge is thus a living barrier that cannot be smothered by a slow rise of sediment. Like dune grasses at the beach, it puts out new roots as dirt builds up around its stems.
- ***Underground Networking:*** Vetiver is a sod-forming grass. Its clumps grow out, and when they intersect with neighbouring ones they intertwine and form a sod. It is this that makes the hedges so tight and compact that they can block the movement of soil.
- ***Clump Integrity:*** For all practical purposes, vetiver has no running rhizomes or stolons[5/] this, too, helps keep the hedge dense and tight. The clumps do not readily die out in the center. Unlike most other clump grasses, even old vetiver plants seldom have empty middles.

4.1.1 Crown

The crown - part between shoot and root of the plant is generally a few centimetres below the surface of the ground. It is a "dome" of old material, debris, and growing tissue, much of it a tangled knot of rhizomes. These rhizomes are very short - 1 cm or less - and are often turned back on themselves. It is apparently for this reason that vetiver stays in clumps and does not spread across the land. *(The statement that vetiver has short rhizomes has been proven to be wrong since vetiver, unlike some other plants, has no rhizome at all (see Chapter 5). The tillers grow from the base of the stout stem in all directions and finally form dense mass of the crown after the tillers produce more tiller-offsprings – Ed.)*



The crowns of vetiver grass

To separate the tillers for planting, the massive crown is cut apart. It is sometimes so huge that it has to be pulled out of the ground with a tractor and cut up with axes. In the nurseries, however, young tillers are easily separated.

4.1.2 Leaves and Stems

It is, of course, the leaves and stems that are crucial in this living-hedge form of erosion control. Vetiver leaf is somewhat like that of the sugarcane, but narrower. Although the blade is soft at the top, the lower portion is firm and hard.

On some vetiver genotypes, the leaves have edges sharp enough to scratch your arm. Actually, this is due to tiny barbs. There is a lot of variability, however. Some plants are fiercely barbed, some not. The ones used for oil and erosion control tend to be smooth edged.

It is the stems that provide the "backbone" of the erosion-control barrier. Strong, hard, and lignified (as in bamboo), they act like a wooden palisade across the hill slope. The strongest are those that bear the inflorescence. These stiff and cane-like culms have prominent nodes that can form roots, which is one of the ways the plant uses to raise when it gets buried. Throughout their length, the culms are usually sheathed with a leaf-like husk. This possibly shields them from stresses; salinity, desiccation, herbicides, or pestilence, for example (National Research Council 1993).

4.1.3 Flowers

The flowers are borne in inflorescence, and the seed-heads are very large, up to 1.5 m long. Both are brown or purple in color. The flower's male and female parts are separated. As in maize, florets in the upper section are male and produce pollens; in vetiver, however, those below are hermaphrodite (both male and female).

4.1.4 Roots

Perhaps most basic to this plant's erosion-fighting ability is its huge spongy mass of roots. These are not only numerous, strong, and fibrous, they tap into soil moisture far below the reach of the roots of most crops. They have been found at depths below 3 m and can keep the plant alive long after most surrounding vegetation has succumbed to drought.

The massive, deep "ground anchor" also means that even heavy downpours cannot undermine the plant or wash it out. Moreover, because the roots anchor steeply downwards, farmers can plough and grow their crops close to the line of grass, so that little cropland is lost when the hedges are in place.

The roots can grow extremely fast. Tillers planted in Malaysia produced roots 60 cm deep in just 3 weeks, and tillers planted in Papua New Guinea produced roots 90 cm in 4 weeks.

It can be concluded that vetiver has special features in its morphological characteristics as follows:

- Vetiver grass has no stolon (unlike cogon grass which has). It has a massive finely structured root system that can grow very fast. This deep root system makes vetiver plant extremely drought tolerant.
- Stiff and erect stems which can stand up to relatively deep water flow.
- Dense hedges are formed when planted close together and form a very effective water spreader, diversion barrier and sediment filter.
- New shoots emerge from the base, helping it to withstanding heavy traffic and heavy grazing pressure.
- New roots are developed from nodes when buried by trapped sediment. Vetiver will continue to grow up with the deposited silt eventually forming terraces, if trapped sediment is not removed.

Picture 12-14: Sample of Vetiver root growths in PNG, China and Thailand respectively.

4.2 PHYSIOLOGICAL CHARACTERISTICS

Like its relatives, maize, sorghum, and sugarcane, vetiver is among the group of plants that use specialized photosynthesis. Plants employing this so-called C_4 pathway, using CO_2 more efficiently than those with the normal (C_3 or Calvin Cycle) photosynthesis. For one thing, most C_4 plants convert CO_2 to sugars using less water, which helps them thrive under dry conditions. For another, they continue growing and "fixing" CO_2 at high rates, even with their stomata partially closed. Since stomata close when a plant is stressed (by drought or salinity, for instance), C_4 plant tend to perform better than most plants under adversity.

The vetiver plant is insensitive to photoperiod and grows and flowers year-round where temperatures permit. It is best suited to open sunlight and will not establish easily under shady conditions. However, once established, plants can survive in deep shade for decades. They tolerate the near darkness under rubber trees and tropical forests, for example (National Research Council 1993).

4.3 ECOLOGICAL CHARACTERISTICS

4.3.1 Ecological Climax

Vetiver is an 'ecological climax' species. It outlasts its neighbours and seems to survive for decades while (at least under normal conditions) showing little or no aggressiveness or colonizing ability (National Research Council 1993). Vetiver can survive months of drought or up to 45 days of flooding. It can be grown at temperatures as low as - 9^{o}C and as high as 45^{o}C. It thrives in sea-level marshes and on mountain 2,600 m high. It flourishes in both acidic (pH 10.5 in India) or alkaline (pH 4.5 in Ethiopia) soil, despite salinity, low fertility, and even aluminium toxicity. Vetiver has positive effect on crops in its vicinity. Because it is virtually sterile, it never becomes a weed or spreads out of control. It has almost no enemies.

Snake, rats and other pests dislike it. But what happens if it is grazed to the ground by starving cattle, or burned to ash in a bush fire? No problem! Like the proverbial phoenix, *vetiver rises again*. How does it stop erosion? When planted correctly, vetiver forms a dense, erect, cheap, easy to establish, permanent hedge at the ground surface that slows the velocity of rainfall runoff to nearly zero, thus greatly increasing both the amount of rain infiltrating the ground and farm productivity. Tests in Malaysia found that vetiver hedges reduced water run- off 75% and soil erosion 93%. Vetiver was planted in Fiji, in 10 m-deep erosion gullies decades ago; now the gullies are no more (Technology 1991).

4.3.2 Effect of Arbuscular Mycorrhizal Fungi on Growth of Vetiver

Inoculation of the roots of vetiver grass with mycorrhizal fungi improves the growth significantly. Note that while some of the fungi were better than others in promoting biomass production, even the least successful of the fungi still improves the growth. The association between the roots of a plant and the vegetative part of a fungus, known as 'mycorrhiza', helps the plant to take up nutrients and soil water more efficiently; this is very important under condition where nutrients and/or moisture are limited.

It was found that by inoculating vetiver roots with certain fungi, early growth and establishment of vetiver were much better. If we establish plants with the right mycorrhiza to rehabilitate and stabilize degraded lands, then the fungi can benefit other crops that will eventually be grown there. Mycorrhizal fungi occur in nearly all soils on earth and form mutualistic symbiosis (an association beneficial to both) with the roots of most terrestrial plants. The arbuscular mycorrhizal fungi (AMF) are present over the widest ecological ranges and are commonly found in association with most of the important agricultural and horticultural crops.(Grimshaw 1991).

Study on soil microbial biodiversity in the rhizosphere of vetiver grass in degrading soil indicates that the total soil microorganisms and cellulolytic microbes have increased from 10^6 to 10^8 cells/g of dry soil. Meanwhile, the endomycorrhiza increased from 2.5 to 25.5 spores/100 g of soil. Increasing the amount of soil microorganisms had also corresponded with the amount of some nutrients in the soil.

The quantities of released phosphorus, potassium, calcium, magnesium, and sulphur increased from 2.2, 51, 375, 353; and 0.82 to 4.7, 148, 495, 537, and 1.63 ppm, respectively. The pH of soil has changed from 5.0 to 5.8. Furthermore, the amount of soil organic matter was raised from 0.50 to 0.90% (Sunathapongsuk *et al*. 2000).

4.4 GENETIC CHARACTERISTICS

In the DNA-fingerprint analysis of genetic diversity of the vetiver, it appears that only one *C. zizanioides,* genotype, 'Sunshine', accounts for almost all germplasm used in soil and water conservation outside South Asia. Additional RAPD analyses revealed, however, that several other non-fertile accessions are distinct genotypes. This germplasm uniformity holds promise for reducing the vulnerable genetic uniformity in what is now essentially a pantropical monoculture of an economically and environmentally important plant resource. Analysis of vetiver cultivars and putative

C. nemoralis from Thailand has suggested that *C. nemoralis* is, in fact, a distinct taxon (Adams 2000).

Cytological data play a very important role in understanding the phylogeny and supporting classification in plant taxa. Vetiver has very specialized adaptations enabling them to grow in various habitats. As a result of hybridization, there are many intermediates occurring in the nature.

Variation in chromosome number within a single species is also common in the Poaceae. The study on chromosome number reveals that *Vetiveria* spp. have base number, x = 10, and 2n = 20 (2x) and 40 (4x) (Namwongprom *et al.* 2000). *Vetiveria filipes,* which is one of the Australian species, is of special botanical interest because its morphology is intermediate between vetiver and lemongrass. One accession was found to have a 2n chromosome number of 40 (=4x), which is twice of that normally found in the genus.

One of vetiver's great benefits, of course, is that once it is planted, it stays in place. It is therefore, not pestiferous, and seldom spreads into neighbouring land.

Actually, though, seeds are often seen on the plant. Why they fail to produce lots of seedlings is still unknown. Perhaps they are sterile. Researchers who examined spikelet and pollen fertility in 75 clones collected from widely different geographical locations within India found that 5 clones failed to flower. Of the remaining 70, female (pistillate) sterility ranged from 30 to 100%; male (pollen) sterility ranged from 2 to 100%. Some, notably those of South Indian origin, could be maintained only by vegetative methods because they produced no seed under natural pollination or under hand pollination, despite high pollen fertility. These data were obtained under New Delhi conditions. Perhaps, they may be fertile, but the optimum conditions for germination are seldom present. Or perhaps people just have not looked hard enough!

Under certain conditions, some seeds are indeed able to germinate. These conditions seem to be most commonly found in tropical swamps. There, in the heat and damp, little vetiver seedlings spring up vigorously all around the mother plant (National Research Council 1993).

4.5 HYDRAULIC CHARATERISTICS

The situation being considered is the use of vetiver hedges in line of structural (water diversion) measures, say > 5%. In doing so, we should remind ourselves that the original natural forest system was a vegetative system that successfully controlled erosion. The aim is to produce an alternative system that combines erosion control with agricultural production. Substantial soil movement is most certainly going to occur. The aim will be restricted to the location of this soil movement, as far as possible, to between the hedges and minimize the amount of soil lost from the slope. The end point of the process will be a sequence of stable natural terraces with the steep batters stabilized by the hedges, as following schematic definition sketch of the vegetative barrier system (Smith 1996).

W1	=	Design width of barrier, m
W2	=	Design width of cropped strip, m
Ws	=	W1+W2 = barrier spacing
S0	=	Initial land slope steepness, m/100m
S1	=	Future barrier back slope steepness, m/100 m
S2	=	Future steepness of cropped interval, m/100 m
Hs	=	Step height of mature vegetative barrier, m.

Trials aimed at a quantitative description of the hydraulic characteristics of vetiver hedges are described. Three hedges were planted across a large outdoor flume, perpendicular to the flow. Trials were conducted at various discharges and depths, and the discharges and depths upstream and downstream of each hedge were recorded. From these data, an empirical hydraulic relationship was developed between the depths and the discharge. This relationship was used to calculate the maximum vetiver hedge spacing required to control soil erosion on a cropped flood plain of low slope subject to deep erosive overland flows. Finally, appropriate hedge spacing was calculated for a field site on the Darling Downs of Queensland, Australia. Hedges were planted at the appropriate spacing and flow retardant and sediment trapping were monitored.

The flow of water through a hedge can be described by a simple equation relating discharge to the depths upstream and downstream of the hedge, with upwards of 90% of the variation in discharge described by the equation. Secondly it appears hydraulically feasible to use vetiver hedges to control flood flow and erosion on a cropped flood plain (Dalton *et al*. 1966).

5. PROPAGATION OF VETIVER

5.1 PROPAGATION Verse MULTIPLICATION

There are a few terms commonly used to describe the mode of reproduction of vetiver. The two most common terms are ‘propagation’ and ‘multiplication’, which are used interchangeably by some authors. Others use the term ‘propagation’ to mean any means of reproduction of vetiver, irrespective of the ultimate goal, while the term ‘multiplication’ is used to solely increase the number of individuals of vetiver plants, without having the objective of planting them in the field. Some authors, however, use the term ‘propagation’ in place of ‘multiplication’, and vice versa.

In this manual, ‘propagation’ is defined as “any means of reproduction, either for increasing the number of individuals or for subsequent planting out in the field”, while ‘multiplication’ is “any means of reproduction solely to increase the number of individuals”. It is implied that ‘propagation’ is used as a general term of reproduction of vetiver; it also includes ‘multiplication’ through various means to increase the number of individuals. The ultimate goal of ‘propagation’ is to grow individual vetiver planting materials in the field, either through the process of ‘multiplication’ first, or directly growing the propagules in the field.

5.2 VETIVER PARTS USED IN PROPAGATION

Vetiver plant in cultivation rarely produces seeds. Thus, only asexual reproduction will be treated in this manual. In the vetiver literature, several terms have been used, sometimes indiscriminately, to designate the parts of the vetiver plant that can be used in propagation. In this manual, all these terms are being compiled, and, to avoid further confusion, their definitions which are based on: (1) Webster’s New World Dictionary, Third College Edition, 1993, written in italics; (2) www.dictionary.com, underlined; and (3) the lecturer’s own, specifically for vetiver, in italics and underlined, are provided together with their explanations. They are given below:

5.2.1 Tiller

Image 2: Artistic drawing of Vetiver tiller

1. A shoot growing from the base of the stem of a plant
2. A shoot, especially one that sprouts from the base of a grass
3. A shoot sprouts from the base of the stem of a vetiver plant.

Tiller is the most popular part of the vetiver plant used in propagation since it is available in large quantity, employs simple technique, and gives good result.

5.2.2 Slip

1. A stem, root, twig, etc. cut or broken off a plant and used for planting or grafting; cutting; scion
2. A part of a plant cut or broken off for planting; a cutting
3. A shoot cut off from a vetiver clump used for planting.

Many authors used this term synonymously with tiller. Some (e.g. National Research Council 1993) even called it a 'root division'. In vetiver, the structure from which the slip grows is the base of the stem, not the root. As it is a rather confusing term, and the fact that the term 'tiller 'is more appropriate, the present paper will not use this term to avoid further confusion.

Picture 15-16: Bare root slips with 3 tillers ready for planting

5.2.3 Culm

Image 3: Vetiver Culm drawing

1. A stalk, stem; the jointed stem of various grasses, usually hollow
2. The stem of a grass
3. The above-ground part of the stem of a vetiver plant.

The culm of the vetiver grass is strong, hard, and lignified, having prominent nodes with lateral buds that can form roots and shoots upon exposure to moist condition. Laying the cut pieces of culms on moist sand, or better under mist spray, results in the rapid formation of roots and shoots at each node.

5.2.4 Cutting

1. A slip or shoot cut away from a plant for rooting or grafting
2. A part of stem removed from a plant to propagate new plants, as through rooting

3. Vetiver culm cut into sections with at least one node each used to propagate new plant.

Although commonly used as propagating material in horticultural crops, ‘cutting’ is rarely used in vetiver. This term is probably synonymous with ‘cut culm’ or ‘culm-cutting’ (as referred to by Yoon 1991).

5.2.5 Culm-branch

1. There is no definition of such a term in Webster’s Dictionary
2. There is also no definition from www.dictionary.com
3. A branch developed from the lateral bud of a culm.

It is a term derived from similar structure in bamboo and other ramified grasses. It was Yoon (1991) who used this term in vetiver literature for the first time to mean a branch developed from a lateral bud of a culm of more than three months old whose main culm has been repeatedly cut down to induce tillering.

5.2.6 Clump

1. A cluster, as of shrubs or trees
2. A thick grouping, as of trees or bushes
3. A cluster of tillers developed originally from a mother plant of the vetiver in all directions.

In vetiver, a clump is formed when a plant has been grown for a certain period and produces numerous tillers in all directions.

5.2.7 Ratoon

1. A shoot growing from the root of a plant (esp. the sugar cane) that has been cut down
2. A shoot sprouting from a plant base as in the banana, pineapple, or sugar cane
3. A shoot (tiller) sprouting from the base of the vetiver plant that has been cut down to induce sprouting.

As vetiver (or even the sugar cane) does not seem to re-sprout from the root when the clump is cut down to the ground, but rather from the base of the stem, thus the re-sprouting structure is actually a ‘tiller’ which has been induced to sprout by cutting down the top part. This term will not be used in this paper to avoid further confusion.

5.2.8 Tissue-cultured plantlet

1. There is no definition of such a term in Webster’s Dictionary
2. There is also no definition from www.dictionary.com
3. Differentiated tiny plant developed from explant through tissue-cultured technique.

Unlimited number of plantlets can be produced in a septic condition from the explants deriving from shoot tip, lateral bud, young inflorescence, etc. Upon attaining a good size, these ‘plantlets’ can be transplanted in the containers or in the fields similar to tillers, although much smaller in size. Tissue-cultured plantlets can be produced within a relatively short time with reasonable expenses. They also have certain advantages over other planting materials in that they are small in size, easy to transport, and free from pathogen (as they are grown, and still remain, in aseptic condition) which makes them safe for international movement, especially across the countries with strict plant quarantine system.

Of all these parts, only the first and the last are used extensively in most vetiver growing countries to propagate the vetiver plant, simply because they are the convenient parts to be used in propagation. Besides, the cost of their production is relatively lower than that of the other parts while the success is higher. Of the remaining structures, culm (including cutting and culm-branch) and clump are also used in propagation to some extent while the rest are either not used for practical reason, or do not exist.

5.3 TECHNIQUES COMMONLY USED IN VETIVER PROPAGATION

5.3.1 Bare-Root Slips in Cultivated Land for Multiplication

This traditional method of planting vetiver has been done since the old days when people started to grow vetiver for erosion control in India some 200 years ago. It was the most convenient method so far practiced in those days when no polybags were available and no other parts were used. This method is still in use even nowadays in many countries.

For multiplication purpose, tiller can also be planted directly on cultivated land. In Thailand, this is normally employed in the government-owned vetiver multiplication centers, such as the Land Development Department’s stations, or multiplication plots of other agencies. These are normally located near the area where vetiver will be transplanted. Depending on the kind of cultivated land used in multiplication, this type of planting can be separated into three categories, viz.:

5.3.1.1 On Upland Fields

Large-scale vetiver multiplication requires a large to number of tillers well suited government agencies, or large-scale plantations or companies. The system is suitable for non-irrigated areas. After land preparation, tillers whose shoots are trimmed to 20 cm and roots to 5 cm are planted when soil is moistened. Two or three tillers are used in each hole at a spacing of 50 x 50 cm. However, to make it easier for caring and best time for the operation is mid-rainy season (between mid-June and mid-August). In this method, each 4-5 month-old tiller can generate an average of 50 new shoots per clump during the period of multiplication of about six months.

Picture 17: Family nursery on an upland field (Kimbe, Papua New Guinea)

5.3.1.2 On Raised Beds

This method should be applied in area where there is a good watering system. Under proper cultivation practice, this system is highly productive. Moreover, tillers can be produced on a year-round basis. The tillers used in planting are obtained from the selected clump, and then trim the top to 20 cm and the roots to 5 cm. After that, the shoots are separated and bound together in bunches. The roots are soaked in water for four days, after which they start to grow. This will give more than 90% survival rate. Tillers are then planted on prepared raised beds of 1 m width with a walk path of 1 m. On each bed, the tillers are planted in double rows at spacing of 50 x 50 cm. watering after planting to maintain soil moisture is necessary. At one month, each tiller should receive approximately one teaspoonful of 15-15-15 fertilizer. Each clump will generate 40-50 new shoots after 4-5 months, and one ha of land can yield 750,000-975,000 new shoots.

Picture 18: Commercial nursery on raised bed (India)

5.3.1.3 In Paddy Fields

This practice is done in the paddy fields with good drainage or other areas having good watering and draining system. The same procedure of the above methods can be applied in this method.

5.3.2 Planting Tillers in Polybags & Transplanting to the Field

This is a technique that has only recently been developed when vetiver has been popularized to be grown for soil and water conservation as the result of promotional campaign of the World Bank in the late 1980s.

5.3.2.1 The Technique

Individual tillers are separated from the clump. The shoot is cut off to about 20cm and the root to about 5cm in length. Each tiller is inserted into a small polybag filled with planting medium, normally composed of burnt rice husk, manure, coir dust, and some topsoil. The techniques of propagation of vetiver employed in various countries differ somewhat. For example, in Thailand, the tillers are planted in polybags for 45 days or more before field planting. The medium used is one part topsoil and one part compost. The best time to transplant is at the beginning of the rainy season. Survival rate is expected to be more than 90%, especially if the rain falls normally (Chalothorn 1998). In Malaysia, Yoon (1991) planted tillers in polybags with sizes of 7” x 15” and 10” x 20”. One nugget of Kokei (6 g) of slow release fertilizer (N, P, K, and Mg) was applied into each bag and a drip-dry irrigation system was used. Plants were divided as soon as they are bag bound. At four months, the small bags had 17.1 + 1.1 tillers/plant and the larger bags 25.5 + 1.6 tillers/plant.

5.3.2.2 Problems in Polybag Propagation

Polybag propagation is by far the most popular technique in vetiver propagation. However, it has many drawbacks such as:

- ✓ **Expensive:** This includes the costs of polybag, medium (topsoil and compost), nursery, water, labour and transportation.

- ✓ **Problems in Maintenance:** A large area of the nursery is needed for keeping the vetiver in polybags for the period of 45 days or more. Watering the young plant everyday requires labour and installation inputs, and a good source of water supply.

- ✓ **Environmental Problem:** The disposal of a large number of polybags during field planting is always a problem since most labourers do not pay attention to collecting the polybags after removing the young vetiver plant out for planting. Instead, the polybags are left in the field, thus creating environmental pollution.

- ✓ **Demand-Supply Problem:** In many cases, the demand for vetiver planting material does not match the supply. Sometimes a large number of polybags with vetiver is available at the multiplication centre while the demand for them is much less. As a result, most of them are to be disposed of, since they are no longer good for planting a few months after their optimum period (of 45 days). In other occasion, there is not enough planting material at the time of need.

- ✓ **Labour Intensifies:** Starting from procurement of medium (topsoil, burnt rice husk, coir dust, and compost), cutting the corner edges of the polybags, filling the medium into the polybag, preparing the tillers, inserting the tillers in the polybags, laying the polybags in the nursery, watering and other maintenance, transporting the polybags to the field, removing the polybags, digging holes for planting, placing the vetiver plants in the hole, covering the holes with soil, collecting used polybags, etc., all are quite time and labour consuming.

Even with all the above drawbacks, planting tiller in polybag is still popularly employed in vetiver propagation in most vetiver-growing countries, as it is the most practical method of propagation.

5.3.2.3 Types of Polybag Propagation

Planting vetiver in the polybags is both clean and easy to maintain; however, it requires proper tools for watering and caring. Depending on the objective, two sizes of polybags are used: **small polybags** for field planting, and **large polybags** for multiplication

- ✓ **In Small Polybags for Field Planting:** This method is appropriate to be used under various development projects in the initial stage of operation. It is very convenient in terms of distribution and providing services or support to various agencies and interested public for further multiplication or other purposes. It is easy to develop and keep a record of the number of bags and tillers needed to meet the demand.

  The size of the polybags is about 5 cm wide and 15 cm long, with a diam. of 7 cm when filled with soil. Many other sizes have also been used in several countries.


Picture 19-20: Nursery in small polybags

- ✓ **In Large Polybags for Multiplication:** The large polybag is made of black polyethylene, about 10cm wide and 25cm long, with folding at the bottom. When filled with planting soil, the bag will have a diameter of 15- 20 cm.

Propagation of vetiver tillers in large polybags can produce a large number of new shoots. These shoots are collectively called clump and can be kept in the poly bags for an extended period of time. Hence, these vetiver clumps are suitable for further multiplication or for separating into individual tillers (bare root) for large - scale transplanting.

Picture 21: Nursery in large polybags (Funafuti, Tuvalu)

5.4 INNOVATIVE TECHNIQUES IN VETIVER PROPAGATION

As planting vetiver for soil and water conservation is getting popular, many new innovative techniques of its propagation have been developed to obtain better result in a shorter period of time with less expense. Among these are:

5.4.1 Tissue-Cultured Technique

As micro propagation through tissue-cultured technique is quite well developed in many vetiver-growing countries, such technique has now been adopted in these countries to mass produce vetiver planting material. This method is appropriate because it does not promote mutation; besides, vetiver plantlets, which are relatively small as compared to conventional tiller in polybags, make it easy for transporting large quantities to other areas (Charanasri et al. 1996).

5.4.2 Planting Specially-Treated Bare-Root Tillers Directly to Field

A new technique in vetiver propagation has been developed by Chalothorn (1998) at the Huai Sai Development Study Center by using bare-root tillers planted directly in the field. The procedure includes digging up the well-developed vetiver clump, chopping the shoot to 20 cm and the roots to 5 cm, then split the clump into individual tillers, tie them together into bundle, and keep them in shallow water for four days (to induce new root formation) before planting. This method is quite efficient; especially if operation is done in the rainy season after the soil has been sufficiently moistened. The survival rate is promising with this method. It is quite convenient and economic since it does not require polybag, medium, or maintenance, and also save a lot of labor. A s compared to the polybag method, transp or tation cost to the s ite of planting is much less .

A further improvement has been invented by Jirasathaworn and Sutharuk (1995, cited by Inthapan and Boonchee 2000) who submerged bare-root tillers in humic acid solution for three days until they produced new roots. They were found to grow faster after transplanting in the field (in the middle of May to the end of June) than tillers grown in polybags.

5.4.3 Planting Tillers in Strips for Field Planting

The Khao Hin Son Royal Development Study Center (1998) has developed a new propagating technique by making a long strip which would facilitate transportation and planting. It is a labor-saving practice with high survival rate since the roots are not disturbed as in the case of using polybags. It is also environmental friendly because no waste material (used polybags) is left in the field.

The materials employed include two rows of cement blocks (each is 20 cm high, 30 cm long and 4 cm thick) placed at a distance of 1.3 m apart and any length depending on the length of the area. Steel rods or bamboo stakes are placed 5-6 cm apart across the width of the cement blocks to support plastic sheet. With a piece of stick, push the sheet down and fill the cavity with planting medium (soil mixed with compost). Plant vetiver tillers along the length of the cavity at the spacing of 5 cm. After two months, the roots will form a closely tight net such that the whole strip can be lifted up without damaging the root system.

Normal nursery practices such as watering and shading are given. No watering is given to the young vetiver plants seven days prior to field planting to reduce the weight of the strips in order to facilitate transportation. In field planting, a grove is made in the soil along the contour of the slope to place the strip in it. Press the soil along the strip tightly. Since the whole strip (of 1 m length) is planted together in one operation, no damage is caused to the root mass; thus every plant starts to grow immediately after planting.

Picture 22: Nursery in strips (Kimbe, Papua New Guinea)

5.4.4 Planting in other Containers and Biodegradable Nursery Blocks

A number of used containers such as soft drink cups, cans, etc. have been tried to hold medium for vetiver growth. It was found that although the growth of the vetiver planted in such containers was good and the cost of the containers is negligible, but there was a problem in transport of vetiver plants still in the containers as well as in pulling the whole mass in the containers up before planting in prepared hole; such operation is likely to damage the root system, causing death or poor growth of the newly planted vetiver tillers.

This approach is very adaptive to planting in critical areas such as on side slope of the highway or rail road, along the newly compressed ridged of the farm ponds or reservoirs, since the block slowly disintegrates while releasing plant nutrient to the growing vetiver plant. Such biodegradable block is also ecological friendly since it is made mainly of organic matter; and no 'garbage' of any kinds is left in the field as compared to polybag technique.

5.4.5 Planting Tillers in Bamboo Pots

Pots were cut from bamboo plant with holes at the end; the holes can be made by using a hand drill or simply by using a nail to open small holes. These bamboo pots can be used where polybags are not readily available. It is an eco-friendly method of nursery. The pots can either be reused or planted out together with the vetiver as it is biodegradable.

Picture 23: Vetiver slips raised in eco-friendly bamboo pots (Goroka, Papua New Guinea)

5.4.6 Using Growth Promoters in Tiller Propagation

Ho et al. (2000) tested three commercial brands of growth hormones and two levels of auxin plus minerals in shortening the growing period of vetiver. By soaking the tillers for 15-20 min in growth hormone solutions and immediately planted in the polybags, the growth rate of the vetiver tillers was found to have increased considerably and can potentially reduce the growing period by as much as 50%. The gain in shoot and root length in just three weeks was almost double that of the control (water). An auxin level of around 0.34 ppm was preferred since this amount did not appreciably inhibit root growth and yet produced a good enough shoot growth.

Bernal (2000) used bencil adenine purine (BAP) and naphthalene acetic acid (NAA) to induce adventitious bud development of vetiver cuttings. It was found that BAP at 500 and 1,500 ppm gave better result than the control treatment, while 10 cm cuttings with 500 ppm NAA and 20 cm cutting without NAA were the two best combinations. When different concentrations of NAA were combined with applied time, it was found that 500 ppm for 60 min gave the best result.

5.5 GUIDELINES TO CHOOSE THE TECHNIQUES OF PROPAGATION

The above document provides up-to-date information of the various techniques of vetiver propagation employed. It is up to the manager of the project to select which one he wants to employ in his project, and how it is accomplished to obtain the best result. The following paragraphs provide the guidelines in choosing the techniques to be used in propagating vetiver and also the ultimate goals in vetiver propagation.

The various techniques of vetiver propagation presented above are an asset for those who are working on the transfer of technology of planting the vetiver grass to the farmers or other users. The followings are the guidelines for the users to choose which one they want to employ:

- Availability of the mother plants
- Availability of the facility
- Availability of the techniques
- The demand of vetiver planting material
- The distance to transport
- The terrain in which the transplanting is to take place.

5.6 GOALS IN VETIVER PROPAGATION

Vetiver is easy to propagate at a relatively low cost. Under normal conditions, propagation by using tillers grown in small polybags will give satisfactory results. However, it has certain disadvantages such as being labor intensive, high weight per plant ratio, and may create environmental problem if polybags are not collected after field planting. Thus other alternative techniques of propagation, e.g. using bare-root tillers, growing tillers in other types of containers, or using tissue-cultured plantlets, may be of some advantages.

Non-conventional parts may also be used in propagation in certain special conditions. These methods are by far much cheaper than if they were to be multiplied by tissue culture method. However, once the principal source for multiplication is established, the normal method of tiller planting should suffice. It is therefore very important to set the goals in propagating vetiver before the operation is started. The following goals are the criteria for the manager of the project to choose appropriate techniques for vetiver propagation.

5.6.1 Quality of Planting Materials

One of the major goals in propagating vetiver is to produce only high-quality planting material. Remember that only high-quality planting material should be used in transplanting in the field. High quality includes healthy and vigorous growth. Poor-quality planting materials will result in slow growth or even death of the transplanted tillers. Even re-planting may be possible at a later date, this will not be as good as when every tiller survives and performs its function the moment it was transplanted.

5.6.2 Low Cost

Efficient nursery management will reduce extra cost of propagating vetiver. However, from a planning perspective, high input approach should be aimed at, especially to produce good quality planting material mentioned above. Nevertheless, especially in large-scale propagation, economic consideration should be of prime importance.

The economies of scale and inputs will help to solve the problem considerably since the bigger the operation the cheaper the unit cost of production. The returns for production for a given input will often be more than pay for themselves. Input and material savings can be tremendous. However, being a living organism, vetiver needs some inputs like water, nutrient, light, etc. It will not grow if no water is provided. Similarly it cannot grow well if it has no nutrient upon which to draw. It cannot compete with weeds or animal grazing. It also needs subdue sunlight for its early growth in the nursery, and brighter sunlight at a later stage, especially during the hardening period (see later).

5.6.3 Hardiness

By its nature, vetiver is a tough plant. However, during its early stage of growth as propagating material grown in any form of containers, it is rather weak, especially when subject to long transportation through rugged terrain in the hot sun before being transplanted. Thus planting material should be durable in the sense that it will withstand such conditions without severe setting back. Since such material is aimed at planting in the field exposing to strong sunlight, a young propagating plant kept in shady nursery for a long time, for example, will not be able to withstand exposure to strong sunlight immediately after transplanting. A period of hardening or acclimatization, i.e. exposure to sunlight, prior to field planting is needed.

5.6.4 Being Easy to Transport

Containerized-planting material is considered most practical. However, it would be quite difficult during transportation if the container is large, and planting medium is bulky and/or heavy. Trays to hold polybags or other containerized planting materials should also be lightweight, small volume and easy to handle. A one-way transport, like the use of strip planting, biodegradable nursery blocks, dibbling tubes (tubes removed and retained), etc. has the advantage in that no containers and other materials are to be collected and returned to the nursery for re-use or throwing away.

6. AGRICULTURAL APPLICATIONS OF THE VETIVER

6.1 SOIL EROSION & ACCEPTANCE OF SOIL CONSERVATION MEASURES

Soil erosion is a natural phenomenon that has been occurring since the early part of geologic time scale. What we see now as broad valleys and wide delta areas have been the results from soil erosion processes; the same being the denuded hills and awful gullies and river canyons. Such kind of erosion can be called geologic erosion. With the evolution of human beings and their acquired knowledge of agriculture - that is a departure from 'hunting and gathering' way of life - erosion by man began. The latter kind of erosion is called accelerated erosion.

In fact, this accelerated soil erosion did not happen at once when man started to grow their crops and tend their animals. At first human beings would do cropping in patches at a small extent. Only when the world population increased to a much higher number that soil erosion and other kinds of land degradation, such as saline soils, acid soils, would occur.

Forest clearing has caused vast land areas to be denuded of trees and soil salinity came into play, which made cropping fail and the land could not support its population any more. In a worldwide scale, soil erosion is considered the most severe form of land degradation.

6.1.1 Mechanisms Causing Soil Erosion

It can be simply described that the soil erosion process involves three steps, i.e. detachment, transportation, and sedimentation. Detachment occurs when soil particles or soil clods detach from the land through any kind of force, such as raindrop impact, flowing water, animal tramping, and even the earth gravity. Transportation occurs when there is a means, such as water flowing on the land as runoff and in streams or rivers. Sedimentation, being the final stage, happens when the force that brings soils particles or soil clods decreases and the materials drop and stay in a new place. Good understanding of these three stages will make the correction or alleviation of soil erosion easier and the goal will be successfully achieved.

6.1.2 Extent of Soil Erosion

Studies on soil erosion and its counter measures have started since a century ago. Investigators in USA, Russia, and many advanced countries were the first to study about it, in order to know what has caused it, what impacts it has caused, and how to alleviate it. The estimation of Pimentel et al. (1995) states that, worldwide, 75 billion tons of soils are being lost from all continents in each year, causing a combined damage of approximately $400 billion. The paper mentions that average soil loss from land in Asia, Africa and Latin America is around 40 t/ha/yr, while in North America and Europe the figure is 17 t/ha/yr. Studies in many countries show differing amounts of soil erosion, the largest being approximately 200 t/ha/yr, and even more in certain locations.

6.1.3 Impacts

Impacts from soil erosion are numerous. Decline in agricultural yield is the most prominent. The loss of topsoil with its high organic matter content and rich soil fauna and flora essential for being a 'productive soil' is considered a big loss that the original conditions cannot be easily returned. One inch of topsoil that may need several hundred years to form may be lost within one or two years after the land is cleared and put for cultivation. Such on-site impact is the matter that many governments are covering in order to improve agricultural productivity in respective countries. Another kind of impact is of the off-site nature. It deals essentially with the sedimentation of soil particles in various streams, rivers, lakes, reservoirs, and estuaries and renders either a large budget for improving existing infrastructures or shortening of their useful life. This is a matter that needs much consideration when planning for soil conservation projects.

6.1.4 Measures to Counter Soil Erosion

Soil conservation was started over a century ago. This kind of work is basically to counter the effects of soil erosion. It has been recorded that a soil conservation service was established as early as 1907 in Iceland, and later in 1937 in USA where much work, both research and implementation were implemented countrywide and has become a blueprint for Australia and several African countries. The work in Thailand started in 1963 with help from the USA when the Land Development Department was established, and now covers all provinces of the country.

When working in soil conservation several kinds of measures have been devised, including physical structures, vegetative methods, agronomic measures and management methods. In the early part the physical structures were thought of as effective in retarding soil loss, but later on it was found to have many obstacles that made them not well accepted by the farmers. This subject will be dealt with in the next part in this paper.

6.1.4.1 Implementation of Soil Conservation

Implementation of soil conservation in countries all over the world was influenced by techniques from North America up to the 1970s, when the measures were largely of structural nature. Vegetative and agronomic measures started to gain attention from that point onward, due to the fact that they would be better accepted by farmers because of several reasons. There was not much interest in knowing if any project or program has succeeded since it was a general understanding that soil conservation is one part of rural development that will benefit both people and land.

Only until the 1980s when several workers in this field noted that those conservation measures implemented by projects had not stayed long or land users in the project areas were not interested in working in their fields to protect their soil, that there started to find out that the maintenance of those measures was at a low level, which means that the project has not succeeded. For example, Hudson (1991) reported only 25% success of FAO funded projects which started in the 1970s, and the rate improved somewhat for those initiated later. Lack of success has prompted workers in several areas of developing world to devise methods, loosely called ‘participatory approaches’, which would hopefully lead future projects to higher rate of success.

For projects, to achieve success means to have those recommended measures accepted and adopted by land users. Since the early to mid-1980s, workers in this field started to talk about success and failure of projects and they looked for the way to improve the success rate through several participatory mechanisms as earlier mentioned.

6.1.4.2 Definitions and Theories of 'Adoption'

The so-called Roger's model (Rogers 1962) puts the 'adoption process' in include altogether five stages, i.e. awareness, interest, evaluation, trial, and adoption. Enters (1997) mentioned that, "… change, i.e. adoption of a new idea or innovation, can take many forms and without outside intervention is based on traditional knowledge and/or on-farm experiments. Most of the soil conservation measures being employed now are the mixture of those based on traditional knowledge and on research.

The dissemination of research results has been the main objective of extension. Until recently the task of extension was viewed as educating farmers or to teach them better land management and the application of soil conservation measures within their fields. This top-down approach is still more common than most of us would like to think. But there is now a broad agreement that extension workers should instead assume the role of facilitators of change and communicators between farmers, researchers, project implementers and policy makers. It is their role to assist farmers in the practices, providing the necessary information and assisting in the evaluation of potential soil conservation practices.

The extensionists must also participate in on-farm research and help farmers to make their decision on how to adjust their farming systems in order to reduce land degradation and improve crop yields, thus improving their standard of living."

Sombatpanit (1993) on the other hand proposed adoption to comprise four major steps, corresponding to the states of mind as perception, attitude, acceptance, and adoption. They may be defined briefly like this:

- **Perception (or Acknowledgement):** Becoming conscious/aware of or having the knowledge of
- **Attitude:** Having manner/feeling toward a person or thing
- **Acceptance:** Acknowledgment or recognition as appropriate, permissible or inevitable
- **Adoption:** Act of taking over into general use especially with little, no change in form

On the other hand, Willcocks and Critchley (1996) put the adoption process in the following pattern:

- Identification
- Evaluation 1 (preliminary)
- Evaluation 2 (technical and socioeconomic monitoring)
- Dissemination and extension
- Adoption

Recently, Erenstein (1999) suggested that there was a step-wise adoption in his work on no-burn, reduced till and mulching criteria. Moreover, there are several words related to this, such as, disadoption, non-adoption, etc.

6.1.5 Why Farmers do not adopt?

While success stories are rare, failure (or non-acceptance/non-adoption) saga abound. Fujisaka (1991) studied six projects in Southeast Asia and found as many as 13 reasons why farmers did not adopt recommended practices. They are:

- Absence of problem
- Inappropriate innovation
- General unawareness
- (Lack of?) facility of the innovation
- Incorrect identification of adoption domain
- Appropriateness of farmers' practice
- Adverse off-site effects
- Non-adoption due to problems from innovation
- Non-adoption due to cost
- Lack of extension
- Insecure land tenure
- Farmers may be 'mining resources'
- Negative social connotations

Undoubtedly there must be much overlapping among them. More systematic study about reasons for non-adoption is needed. However, we have to accept the fact that farmers do not accept innovations they are not unreasonable; they are mostly rational.

What Fujisaka has cited above have in fact corresponded with what Hudson (1982) has earlier described about problems of implementing soil conservation in developing countries. Such problems cover political aspects (political policy, state land and state forests, land allocation, legislation), social features (land ownership and land tenure, land fragmentation, social significance of cattle, reluctance to move, reluctance to change), and economic constraints (element of risk, time scale of soil conservation, who should be the one to pay).

Many project which have not found satisfactory success might have a stumbled on one or more problems mentioned above.

6.1.6 Examples of Adoption in Soil Conservation

6.1.6.1 Autonomous Adoption

Erenstein (1999) described about adoption of soil conservation measures that were done without any influence from extension officers by using the term "autonomous adoption". Examples of these are mostly indigenous conservation measures such as cut-off drain, contour trashline, and various kinds of bench terrace that were executed through local wisdom since centuries ago. Ifugao rice terraces in the northern part of the Philippines and ancient Inca terraces at Machu Picchu in Peru are good examples of the practice.

It is, however, evident that the original purpose of building such structures was not for conserving soil; conservation of water and facilitating the work in the field were what inspired to shape their terraces, and facilitation of everyday life was the purpose of those at Machu Picchu. But these structures have served the purpose as the prototypes of modern soil conservation measures such as bench terraces, small terraces for rubber, intermittent terraces for horticulture, hillside ditches, and so on.

6.1.6.2 Adoption through intervention

This is the adoption of soil conservation measures that find favor with farmers, though sometime it needs certain strategies such as financial assistance in the form of incentives in order to induce initial adoption. But once farmers get used to and become aware of those measures, they will continue maintaining them almost without any more assistance. Following are examples of this kind of adoption.

1. **Small bench terrace for rubber in Southeast Asia.** There has been a program to assist rubber farmers in Thailand (and other SE Asian countries) in felling old rubber trees and plant new varieties on the contour. The agency gave money enough for implementing the whole process within the period of five years. Aligning contour lines and putting up a small terrace has to be done in the land preparation process. When farmers get used to bench terracing, including having been facilitated by such kind of structure while working in the plantation, such practice has become a way of life that, when they replant rubber even outside the program, they would try to do the same. After all, they find it very useful when traversing in the farm.

2. **Sloping Agricultural Land Technology (SALT).** The Mindanao Baptist Rural Life Center (MBRLC) in the Philippines has devised the SALT technique comprising growing contour hedgerows (using leguminous shrubs such as Leucaena leucocephala, Cajanus cajan, etc.) on sloping upland and planting cash crops between the rows, and extend it to farmers in Mindanao and other regions of the country (Palmer et al. 1999). The technique has grown far and wide, so that the extension programs in Thailand, Nepal, Sri Lanka and some other Asian countries recommend this technique to their farmer cooperators and got accepted reasonably well comparing with other soil conservation measures, especially the structural ones. Surprisingly, such technique has also been independently developed in West Africa around the mid-20th century (Rattan Lal - Pers. Comm.) and was further promoted in that part of the world.

3 Landcare movement in Australia. There is a highly successful program in getting rural as well as urban people in all states and territories of Australia to involve in caring for the land, rivers, shorelines, native vegetation, etc. While the government coordinates and stimulates the forming of Landcare groups and their implementation, with certain amounts of funding to support, people will organize by themselves to work among themselves. This kind of success could be attributed to the high level of education and awareness of farmers and extensionists alike, and good economy of the country. Up to now, around 4,500 Landcare Groups have been formed across the country, involving approximately one-third of Australian population. Several countries including

New Zealand, the Philippines, and South Africa have now started a similar movement with a good prospect.

6.1.7 How the Adoption Rate can be improved?

In Soil Conservation Extension (Sombatpanit et al. 1997), Strategies needed for extending soil conservation to farmers successfully include (among other things):

- A holistic outlook of 'Land Management'
- Farmers participation
- Use of appropriate technologies and applicable approaches
- Integrating of responsibility among government agencies and NGOs, and
- Wise use of subsidies and incentives

In fact, technologies for conserving soil are mostly simple and straight forward, especially to sufficiently educated people; but to apply them to the land, with farmers to be involved with, is not easy and there are examples of failure everywhere. Many past loan projects might appear nice and successful in the eyes of the local, though some evaluation results being kept in the office of donors or creditors might indicate a certain project to be as bad as a 'total disaster'. Since the publication appeared there has been much progress in several aspects.

6.1.7.1 A Holistic Outlook of 'Land Management'

After the mid-1980s there have been a movement in recognizing 'land husbandry' as a discipline that would well cover soil conservation and many other branches of resource conservation in the manner that, when you husband your land well, soil will be automatically conserved. One major result from that was the establishment of the Association of Better Land Husbandry (AB LH) with headquarters in the UK.

The land husbandry concept still prevails and has become endorsed by the Workshop on Issues and Options in the Design of Soil and Water Conservation Projects (McDonald and Brown, 1999), which point out that land husbandry, along with crop husbandry and animal husbandry, will play their roles in creating sustainable rural livelihoods, which is considered a more realistic goal of 'development' than just to keep the soil in its place, the major purpose of soil conservation.

6.1.7.2 Farmers Participation

There are large numbers of literature in the field of 'participatory approaches'. This term has now become a buzzword, and such participatory principle is considered an imperative for resource management and conservation projects, which have other rural development aspects like health, education and infrastructure to involve with. In studying to more details, workers in this field have gone to the matters of assets which comprise five types of capital: natural, social, human, physical and financial (Pretty and Frank, 2000). With more interest in practicing participatory approaches, the future of adoption of soil conservation measures seems bright.

6.1.7.3 Use of Appropriate Technologies and Applicable Approaches

The World Overview of Conservation Approaches and Technologies (WOCAT) Project, with worldwide cooperating agencies and its secretariat in Berne, Switzerland, has been collating available and successful soil conservation technologies and approaches from several developing countries in Africa, Asia and Latin America (Giger et al. 1999). An 'approach' is simply defined as the ways to get soil conservation measure(s) implemented. Over 100 technologies and around 75 approaches have been digitally catalogued so far, and more are going to be added during these few more years. With results in the digital format, there will be available handbooks for technologies and approaches as well as WOCAT maps to be used as tools for implementing future soil conservation projects.

6.1.7.4 Integration of Responsibility among Govt Agencies and NGOs

Several NGOs are strong and have wide area of operation. It has been observed that some NGOs have gained ground in certain discussion arena, especially concerning solving conflicts in resources use and management between government and rural people who are at the disadvantage status.

6.1.7.5 Wise Use of Subsidies and Incentives

Since 1996, the World Association of Soil and Water conservation (WASWC) has started the project to produce a book concerning the use of incentives in soil conservation projects. The Association can now present its product as the book under the title "Incentives in Soil conservation: From Theory to Practice" (Sander s et al., 1999). The Association hopes that several case studies picked up from all over the world will be useful especially for participants who are working as project planners, implementers and evaluators.

Reij (1998) in his paper on "How to increase the adoption of improved land management practices by farmers", he cites the need for project implementers to find 'triggering mechanism s'. This is similar to what Sombatpanit et al. (1993) called 'narrow path', which blocks a smooth running of project operation. When there is something to trigger (same as when a path is widened), an adoption will be achieved almost very fast.

6.1.8 Conclusions

Soil conservation is a kind of work which is not an end in itself; the measures need good understanding of people who create them in order to have proper maintenance and necessary follow up, so to reach the expected usefulness in sustainable land management. In so doing, a number of strategies are needed in order to gain the adoption from land users towards those soil conservation measures. In studying about farmers' adoption it is necessary to distinguish whether an adoption is real or apparent; when agencies constructed everything for farmers without their involvement and farmers agree to have such deed done in their farms that should not be called 'adoption' at all.

There are several methods that help in increasing farmers' adoption rate of soil conservation technologies. Apart from other conventional extension methods, finding proper triggering mechanisms seems to function well and hence the soil conservation measures created will stay, with a long lasting effect.

Since the adoption is quite essential in the matter of sustainability, both to the measures themselves and to the land and livelihoods as a whole, a thorough study of this essential item is suggested to be carried out, which will give a good example of human behaviour towards innovations, so that new innovations to receive good adoption by land users will be created in the future.

For the time being, it is suggested that any kind of soil conservation measures that does not gain acceptance and adoption by farmers should not be used for promoting to the farmers at all. Too much of financial resources have already been wasted.

6.2 THE USE OF VETIVER FOR SOIL & WATER CONSERVATION

As a clonal plant, vetiver forms dense hedges when planted closely in rows, resulting in a living porous barrier which slows and spreads run off water and traps sediment. As water flow is slowed down, its erosive power is reduced and at the same time allows more time for water infiltrate to the soil, and any eroded material trapped by the hedges. An effective hedge will reduce soil erosion, conserve soil moisture and trap sediment in the run-off water on site. Most vegetative hedges can achieve the same results as vetiver grass, but due to its extraordinary and unique morphological and physiological characteristics previously detailed vetiver has many advantages over other systems tested. This is evident in the following sections:

6.2.1 Soil Erosion and Sediment Control on Sloping Lands

The use of vetiver for soil and sediment control can be exemplified in the following cases:

- In Fiji, the concept of using vetiver grass for soil and water conservation purposes instead of conventional structures was first developed in this country for the sugarcane growers approximately 60 years ago. The vetiver system however is no longer in use apart from a few farmers who still have some patches of vetiver hedges, particularly on small farms. As in other countries, VGT has proven to be very effective in soil erosion control, and when properly implemented the system has improved sugarcane yield up to 55%.

- In Queensland, soil conservation structures and land management techniques have been used to reduce water erosion on cropping and grazing lands. Engineering structures include diversion banks to divert runoff from upper non-arable land, contour banks (terraces), strategic row direction in low slopes and constructed waterways have been used.

- In Australia, VS was used as a replacement of contour banks in steep sugarcane lands on the wet tropical coast where the traditional method of soil conservation using contour banks (terraces) is not acceptable to farmers as the channels and banks can be dangerous for large machinery operations and vetiver hedges offer a solution to that problem.

- In India, on shallow gravelly Alfisol with 2.5% slope, vetiver hedge on contour reduced the run off by 76% and soil loss 97%, and increased mean soil moisture by 5 - 9% in the 0 - 45 cm depth. Increase sorghum, redgram and castor yields due to vetiver hedges ranged from 7.0 - 22.4%.

- In Zimbabwe VGT is being used extensively in large sugar estate and similar to South Africa, VGT is instrumental in the stabilization of farm roads, erosion control in sugarcane fields and particularly in drainage ditches and irrigation channels.

6.2.2 Soil Erosion and Sediment Control on Floodplain

The use of vetiver for soil erosion and sediment control on floodplains are exemplified in the following cases:

- Vetiver System (VS) has been used as an alternative to strip cropping practice on the flood plain of Queensland. (Truong 2000). This practice relies on the stubble of previous crops for erosion control of fallow land and young crops. On this experimental site, vetiver hedges that were established at 90m interval provided a permanent protection against flooded water. Results over the last five years (including several major flood events) have shown that VS is very successful in reducing flood velocity and limiting soil movement, with very little erosion in fallow strips.

- Erosion by wave action can be eliminated by planting a row of vetiver on the edge of the high water mark. Being able to establish and thrive under waterlogged conditions, vetiver has proved to be very effective in r educing erosion cause d by wave action on big farm dam walls.

6.2.3 Flood Erosion Control

The use of VS in flood erosion control can be visualized in the following cases:

- The incorporation of vetiver hedges as an alternative to strip cropping on floodplains has resulted in more flexibility, more easily managed land and more effective spreading of flood flows in drought years and with low stubble producing crops. An added benefit is that the area cropped at any one time could be increased by up to 30%.

- Flood plain runoff and the impact of erosion on the flood plain is a big problem in Queensland where cultivation occurs. Strip cropping at right angles to the slope has been used to reduce the impact of erosion. The shift from high stubble crops such as wheat and sorghum to cotton has reduced the effectiveness of the strips. Vetiver grass planted right angle to the flood flow, i.e. parallel to the crop rows, has been used in these flood plain cropping areas as a vegetative water spreader and filter to reduce soil loss. The land is generally flat in the flood plain hence the vetiver strip should extend the full width of the flood plain to reduce the impact from diverting water flows in peak flood events.

- In Australia, VS has been used successfully on floodplain of the Darling Downs, Queensland, as an alternative to strip cropping practice which relies on the stubble of previous crops for erosion control of fallow land and young crops. Results over the last several years, including several major flood events have shown that VGT were very successful in reducing flood velocity and limiting soil movement, resulting in very little erosion in fallow strips and a young sorghum crop was completely protected from flood damage.

6.2.4 Slope Stabilization

On steep slopes, vetiver hedgerows can stabilize the slopes as evident in the following cases:

- In forest plantation, vetiver has been used successfully to stabilize shoulders of driving tracks on very steep slopes as well as gullies developed following harvests.

- On the very steep slopes (40-50°) in northern Thailand, where the slash-and-burn practice is widespread, vetiver hedges was used to build up terraces on which cash crops such as bean, corn, etc. or exotic fruit trees such as low-chill plum, peach, or apricot can be grown. These crops not only give higher-value product, they also cause much less erosion than root crops such as cassava or sweet potato.

- Gully erosion can be effectively stabilized by vetiver hedges. When planted on contour line above gully head, vetiver hedges will spread and slow down runoff water and stop the advancement of gully heads. This is well illustrated at a number of gullies in both cropping and grazing lands. Following the control of active erosion at the gully heads, gully floors are normally revegetated naturally with native species.

6.3 The Use of Vetiver for Soil and Water Conservation on Farmlands in Northern Thailand

The northern part of Thailand covers an area of about one third of the country (17 million ha), comprising 52% highlands area, 33% uplands, and 15% lowlands. Particularly, the upper northern part (8.58 million ha) has 72% of highlands, 16.7% of upland, and 11.3% of lowlands and water areas (Inthapan et al. 2000). Increase in the pressures of hill-tribe population and the land in the low-land agricultural areas, the forest encroachment was increased markedly in the highlands for slash-and-burn and shifting cultivation.

Soils are degraded because erosion rate increases rapidly each year. The estimate soil loss was from 50-300 t/ha/yr (Inthapan et al.1996). Economic loss, calculated from the value of N, P and K, was equivalent to about $ 95/year (DLD 1999). As a consequence of the traditional cropping system without soil and water conservation system and the proper crop management, soil fertility and crop yield were decreased. Consequently, farmers' life is impeded; it is also posting great threats to the environment and ecological balance. In particular, soil, water, and forest are being destroyed rapidly.

The following part summarizes the results on vetiver experiment of the Land Development Department conducted in the upper north of Thailand since 1990. These researches emphasize on the study of the use of vetiver to fight against soil erosion on sloping farmlands in the north of Thailand.

6.3.1 Number of rows of Vetiver Hedgerows for Erosion Control

In a study of vetiver hedgerow on sloping lands for soil and water conservation, numbers of rows of vetiver hedge are related to the number of tillers - the more number of rows of vetiver hedge, the more vetiver tillers. Reducing number of rows of vetiver hedge can save the number of tillers. Therefore, a study of row numbers of vetiver hedgerow for soil and water conservation is very essential for the farmers. Inthapan et al. (1996) conducted the study on row number of vetiver, ecotype 'Sri Langka' on Tha Yang soil series (Soil Unit Group 48), characterized as sandy loam soil, shallow soil with gravelly in subsoil, and low soil fertility, and ease to erosion surface, on 20% slope located on 600 m.asl., having 1,374 mm of rainfall annually. The result indicated that single and double rows with 30 cm row spacing and 10 cm hill spacing provided non-significant difference in soil and water conservation, whereas they were different from farmers' practice with no vetiver hedge. Single row planting of vetiver hedgerow produced 0.95 t/ha of soil loss while double-row hedgerow gave only 0.71 t/ha of soil loss, or about 12.4% of farmers' practice with no vetiver hedge (Table 1).

Table1: Effect of row number of vetiver hedge on soil loss (t/ha), Chiang Mai

Treatments	Soil Loss (t/ha)
1. Farmers practice	5.70 a*
2. Single-row planting	0.95 b
3. Double-row planting	0.71 b

*Figures followed by different letters indicating significant difference at 95%
Source: Inthapan et al. (1996)

6.3.2 Plant Spacing and Hill Spacing for Erosion Control

Study of plant spacing and hill spacing can indicate how plant and hill spacing influenced soil and water conservation. Inthapan et al. (1996) studied the different plant and hill spacing on sloping lands. The result indicated that 10, 15, and 20 cm hill spacing were good, and not significantly different for soil and water conservation, whereas they differed from the farmers' practice with no vetiver hedge. Soil loss of trial with vetiver hedgerow was only 14.6% of trial with farmers' practice (Table 2). However, vetiver hedge with close hill
Spacing (10 cm) enhanced tiller growth and development to form dense row very fast, and was quite effective for soil and water conservation.

Table 2: Effect of hill spacing of vetiver hedge on soil loss (t/ha). Chiang Mai

Treatments	Soil loss (t/ha)
1. Farmers practice	5.70 a*
2. Hill spacing 10 cm	0.87 b
3. Hill spacing 15 cm	0.82 b
4. Hill spacing 20 cm	0.80 b

* Figures followed by different letters indicating significant difference at 95%
* Source: Inthapan etal.(1996).

6.3.3 Vertical Interval of Vetiver Hedgerow for Erosion Control

The effect of vetiver hedgerow at different vertical intervals on soil and water conservation was conducted by Inthapan et al. (1995). The results obtained during 1993-95 showed that different intervals were more or less the same, and not significantly different in soil erosion measured. An average soil loss was 3.27 t/ha, and only 59 and 31% of those farmers' practice and without vetiver hedgerow treatments, respectively (Table 3).

Table 3: Effect of vetiver hedgerow at different vertical interval on soil erosion in 1993-1995. Chiang Mai

Treatments	Soil Loss (t/ha)
1. Bare Soil	26.05 a*
2. Farmers' practice (corn/black bean)	5.49 b
3. Counter planting (corn/black bean)	3.76 b
4. Counter planting + vetiver (VI = 1 m)	3.08 b
5. Counter planting + vetiver (VI = 2 m)	3.32 b
6. Counter planting + vetiver (VI = 3 m)	3.41 b

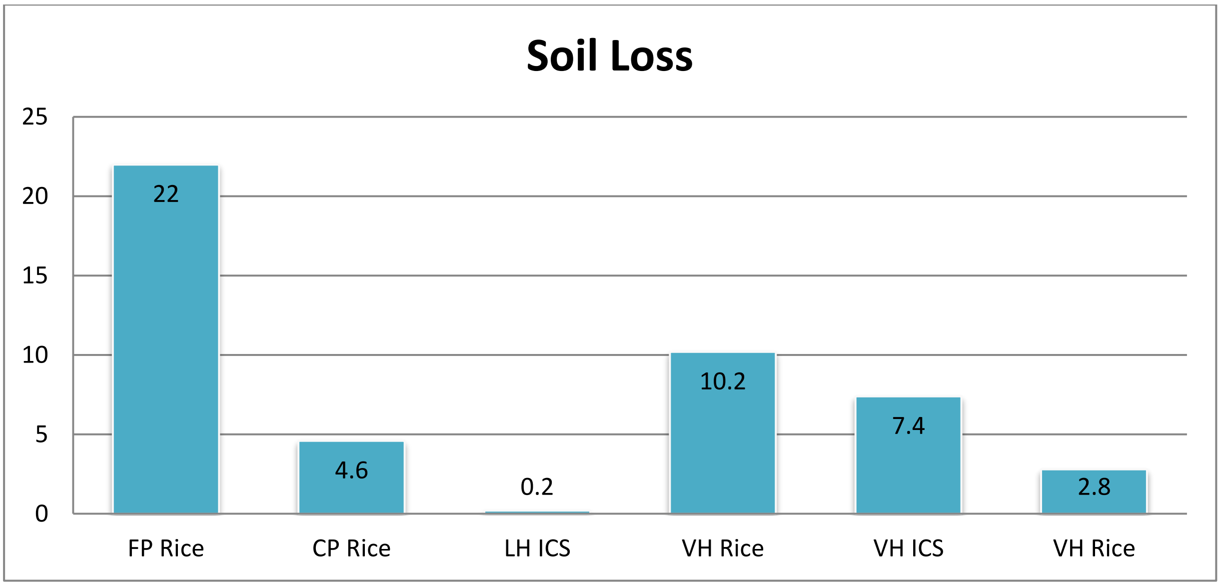
VI = Vertical Interval
** Figures followed by different letters indicating significant difference at 95%*
Source: Inthapan et al. (1996).

6.3.4 A Study of a Comparison of Vetiver Hedgerow with Other Grass or Leguminous Hedgerows

Peukrai *et al. (*1994) studied a comparison of vetiver ecotype 'Sri Lanka' hedgerow with leguminous hedgerow (leucaena and pigeon pea) at Pang Mapha district, Mae Hong Son province, on the slope complex soil (SC) located at 900 m.asl. With 20-40% slope and 1,261 mm of rain per annum. The vertical interval of vetiver hedgerows and leguminous hedgerows was 3.0 m. In 1992-93, a comparison of upland rice and integrated cropping system planting between the hedgerows showed that they were both good for soil and water conservation, with soil loss of both stripes at only 39 and 17% of that f arm er s' practice (Fi g. 1) .

- According to this study, it was found that vetiver and leguminous hedgerows with integrated cropping system along the hedgerows reduced soil loss average, with a soil loss of about 3.8 t/ha, or only 18% of that upland rice monocrop in farmers' practice treatment.

- In addition, Kanchanadul *et al.* (1998) studied 'Sri Lanka' vetiver hedge, comparing of natural grass strip and conservation cropping system at Ban Huai Chakan, Ping Kong district, Chiang Mai province, on Wang Hi soil series, with 25% slope and 600 m.asl.
- Study indicated that all treatments were not significantly different in soil and water conservation, while they differed from that of farmers' practice with mono cropping upland rice. Table 4 shows that the amounts of soil loss and water runoff from those treatments were about 52 and 82% of that farmers' practice with upland rice, respectively. This is due to the fact that the hedgerow (vetiver and leguminous shrub) and natural grass strip can reduce soil and water run- off which enhance more water infiltration, providing soil moisture available for crop growth, particularly, in the dry period.



Key:

FP	Farmers Practice
VH	Leguminous Hedgerow
ICS	Integrated Cropping System
CP	Contour Planting
LH	Leguminous Hedgerows

Source: *Peukrai et al. (1994).*

Graph 2: Amount of Soil Loss (9t/ha) from different treatment at Mae Hong Son Province in 1992

Table 4. Effect of conservation cropping system on soil loss (t/ha) and runoff (m^3/ha) at Chiang Mai site during 1993-95.

Treatments	Run-off (m^3/ha)	Soil loss (t/ha)
1. Upland rice	5800	2.41 a*
2.Upland rice/peanut/vetiver hedge	4819	1.27 b
3. Upland rice/peanut/natural grass strip	4738	1.21 b
4. Upland rice/peanut/NFT @hedge	4781	1.28 b

@NFT = leucaena + pigion pea. **Source:** Kanchanadul et al.(1998).
* The figure are followed by the different letters indicating on significant different at 95%.

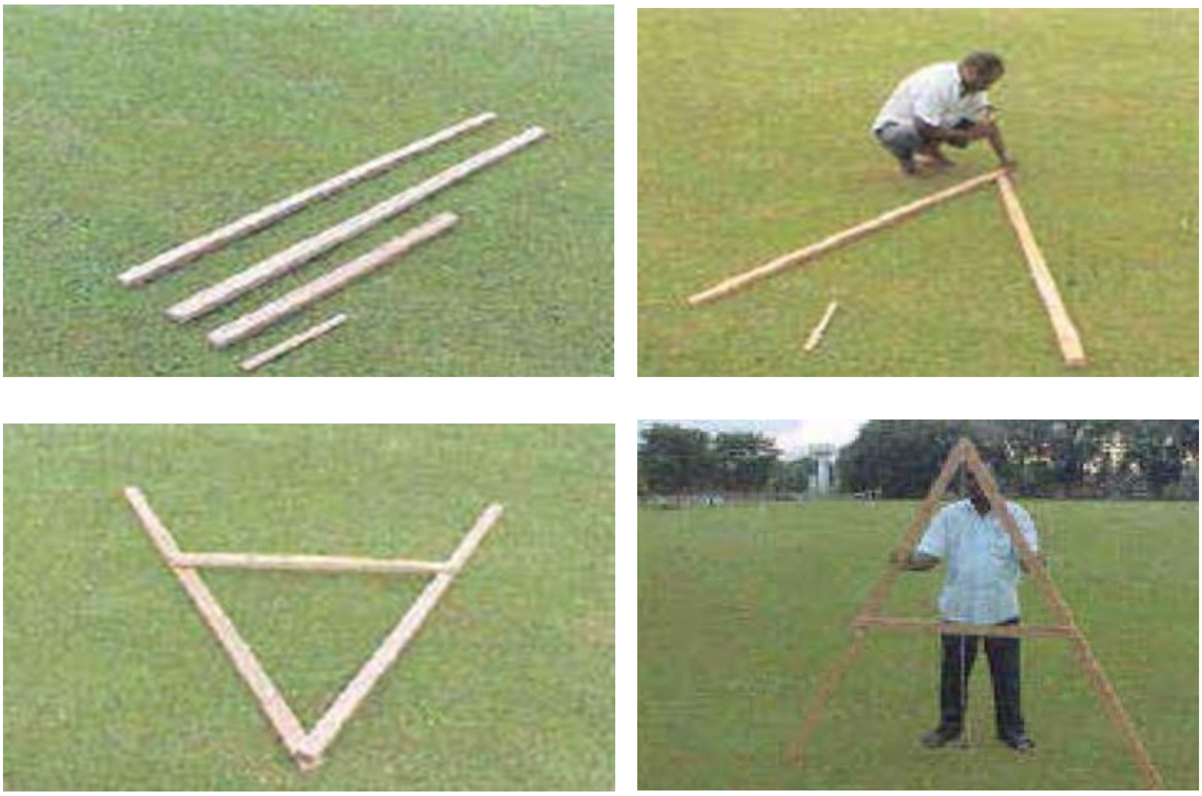
6.4 Techniques of Application of Vetiver Hedgerows on Sloping Farmlands

To apply the proper vetiver hedgerows on sloping farmland requires appropriate techniques. These are described below:

6.4.1 Making an A-Frame Instrument

The first instrument you need is an A-frame. This is a simple, yet effective tool, which looks like the letter A, thus its name. The A-frame is so simple that you can make your own, using materials generally found in your farm. To make an A-frame, three sturdy wooden or bamboo poles, an ordinary carpenter’s levelling instrument, and a string or a rope, are needed. Cut two pieces of wood, at least 1-2 m long to serve as the legs of the A-frame. Cut the third piece, at least 1 m long, to serve as the crossbar of the frame. Tie together the upper ends of the longer poles. Let the lower ends of the legs stand on level ground. Spread the legs about 1 m apart to form a perfect angle. Brace horizontally the shorter pole to become a crossbar between the two legs. Tie the carpenter's levelling instrument on top of the crossbar.

Use the A-frame to layout the contour lines of the land. Soil erosion can be prevented by ploughing and planting along the contour lines. The contour line is a level line from one end of the field to the other, and is found around the hill or mountain



Picture 24 –27: A-frame instrument

6.4.2 Contour Line Layout

Cut tall grasses and remove any obstructions so that you can move easily and mark the line. Two people will make the work much easier and faster. One will operate the A-frame while the other marks the location of the contour lines with stakes. Make a study of the area for which contour lines are to be determined. Begin marking contour lines near the highest point. Let the A-frame stand on the ground. Without moving the rear leg, lift the front leg. Then put the front leg down on the ground that is on the same level with the rear leg. The two legs of the A-frame are on the same level when the air space in the levelling instrument stops in the middle. When this happens, it means that you have found the contour line that is a level line between the two legs of the A-frame. Mark with a stake the spot where the rear leg stands. Move the A-frame forward by placing the rear leg on the spot when the front leg stood before. Adjust the front leg again until it levels of with the rear leg.

For every two to three meters of contour line you find, mark it with a stake. Follow this procedure until you reach the entire length of the contour line that is the other side of the mountain or hill. Try to locate as many contour lines as possible. The contour lines should be spaced from 8 to 10 m apart. Contour line layout by A-frame


Picture 28: Demonstrating how to use the A-frame instrument

6.4.3 Planting Vetiver Tillers along Contour Lines

Vetiver tillers are prepared in the nursery 45 days before planting in the field. Bare root tillers can be used for planting in the moist soil after few days of rainfall. Optimum planting duration is between mid-May to the end of July, when soil moisture is adequate.

6.4.4 Planting Short-term and Permanent Crops

You can plant short-term and medium-term, income-producing crops between strips of permanent crops as a source of food and a regular income while waiting for the permanent crops to bear fruits. Suggested short and medium-term crops are pineapple, ginger, gabi, castor bean, cayote, peanut, mungbean, melon, sorghum, corn, upland rice, etc. To avoid shading, short plants are planted away from tall ones. All these crops plant along contour line parallel with vetiver hedgerows.

6.4.5 Practice Crop Rotation

A good way of rotating is to plant grains (corn, upland rice, sorghum, etc.), tubers (cayote, cassava, taro, etc.) and other crops (pineapple, castor bean, etc.) on strips where legumes (mungbean, bush sitao, peanut, cowpea, lablab bean, etc.) were planted previously and vice versa. This practice will help maintain the fertility and good condition of your soil. Other management practices in crop growing like mulching weeding and pest and insect control should be done regularly.

6.4.6 Fruit Trees and Vetiver Hedge

The land with existing orchards is considered a complete system which is already secure and sustainable. Therefore, similar to the fertile forests, cultivation of vetiver grass is neither necessary nor appropriate in such areas because the grass cannot grow as it normally does owing to weak exposure to sunlight. However, vetiver grass hedgerows can be established in the areas that face drought and erosion. If the perennial trees are not older than 3 years or are not close enough to one another, vetiver grass can be grown in rows parallel with the rows of fruit trees outside the shade, in a circle around the fruit trees at a radius of 1.5-2.0 m. on flat land, or in an inverted semi-circle on sloping land. By this way, vetiver leaves can also serve as mulch covering the base of the trees to help maintain soil moisture and prevent soil erosion.

Picture 29-30: Planting Vetiver tillers along contour lines (Goroka Papua New Guinea)

Picture 31: Permanent crops and vetiver hedgerows

Picture 32: Short-term crops and vetiver hedgerows

Picture 33: Diversified Cropping Systems

Picture 34 – 35: A circle and a half-circle of vetiver hedge around fruit trees

6.5 OTHER BENEFITS OF VETIVER HEDGEROW

6.5.1 Soil Moisture Conservation

To conserve soil moisture in orchards, planting vetiver grass in semi-circle of 2m radius down slope from the tree will give best results, followed by semi-circle of 4m radius and the planting of straight row 4m from the trees conserved the least moisture.

6.5.2 Watershed and Catchment Management

Vetiver System has been used extensively and successfully in India for catchment hydrology management.

6.5.3 Biological Pest Control

Research conducted at Guangxi University, China (Chen 1999) showed that of the 79 species of insect found on the vetiver rows, only four attacked young vetiver leaves. However due to their small population the damage was minimal. On the contrary, 30 other species found in the vetiver rows are considered beneficial insects, as they are the all-important prey enemy of garden, agriculture and forest pests. This indicates that an Integrated Pest Management scheme is put into operation when vetiver is introduced to a new environment.

In Thailand, methanol extracts of ground stem and root were found to be very effective in preventing the germination of a number of both monocotyledon and dicotyledon weed species. These results indicate the potential of vetiver extract as a natural pre-emergent herbicide.

6.5.4Phytoremedial Applications

Phytoremediation (Greek: *phyton* = plant; Latin: *remediare* = remedy) is the use of plants and trees to clean up contaminated soils and water. It is an aesthetically pleasing, passive, solar energy driven clean-up technique. It can be used along with or, in some cases, in place of mechanical methods. This ‘green-clean’ technology is very popular in the U.S. nowadays, not only because it is environmentally friendly, but it also costs around one-tenth to one-third of conventional remediation technologies. It is expected that in the U.S. the use of phytoremediation techniques will increase more than 10 folds in the next few years. For the rest of the world, it is likely that this trend will also be followed. (Hengchaovanich 2000).

As mentioned in the earlier section, VS are used to remove contaminants. Most plants used in the western world are popular trees, some other grasses and wetland plants. Research over the last few years, in particular those conducted by Truong and Baker (1998), shows that vetiver is an ideal plant for such purpose. His findings showed that it is highly tolerant to toxicity of heavy metals such as Al, Mn, As, Cd, Cr, Ni, Pb, Hg, Se and Zn. It is capable of absorbing dissolved N, P, Hg, Cd and Pb in polluted water. Moreover, being a wetland plant itself, vetiver can also be used in a constructed wetland system.

In Thailand, it was reported that vetiver could decontaminate agrochemicals, especially pesticides and prevented them from accumulating in crops, polluting streams and other ecosystems (Pinthong *et al.* 1996). Experiments carried out to determine the possibility of using vetiver grass to treat wastewater was proven successful, it was found that vetiver can uptake significant amount of N, P, K, Ca, Mg, Pb, Cd and Hg.(Sripen *et al*. 1996). Laboratory results also showed the ability of vetiver in absorbing heavy metals (Roongtanakiat *et al*.1999).

6.5.5 Trapping Agrochemicals and Nutrients

Vetiver systems have been shown to be very effective in trapping both fine and coarse sediments in runoff water from both agricultural and industrial lands (Meyer *et al*. 1995; Truong *et al.* 1996; Truong 1999). In addition, vetiver grass has a very high level of tolerance to extremely adverse conditions including heavy metal toxicity. Therefore VS, when appropriately applied can be a very effective and low cost means of reducing particle-bound nutrients and agrochemicals in runoff water from agricultural lands. The study of VS in trapping nutrients, herbicides and insecticides in runoff from two major agricultural industries in Australia - sugarcane and cotton. (Truong *et al*. 2000).

The results showed that vetiver hedges have proven to be an effective vegetative filter to reduce sediment bound pollutants such as endosulfan and phosphorus in cotton farm. Although pesticide and herbicide levels were not determined in the sugarcane trial, similar results to those from the cotton trial can be expected with these agrochemicals, as a very high proportion of P and Ca was trapped by the hedges.

Vetiver has played an important role in the retention and decontamination of agrochemicals, especially pesticides, preventing them from contaminating and accumulating in the soils and crops. Research conducted in cabbage crops grown on steep slope (60%) in Thailand indicated that vetiver hedges had an important role in the process of captivity and decontamination of agrochemicals especially pesticides such as carbofuran, monocrotophos and an anchor, preventing them from contaminating and accumulating in the soils and crops.

7. NON AGICULTURAL APPLICATIONS

7.1 Bioengineering

In many parts of the world, especially the tropical monsoon belt, rainy or monsoon season is a common yearly phenomenon. Intense and heavy rainfall incidences with precipitation ranging from 1,000 to 4,500 mm per annum are normally anticipated, depending on geographical locations.

Infrastructure projects in this region are therefore known to be fraught with rainfall-induced erosion, shallow mass movement and/or deep seated stability problems caused in the main by the removal of natural vegetation in the first instance. Of all these occurrences, construction activities especially contribute some 20 times the rate of other forms of erosion attributable to land use on the average.

A separate survey in China showed that the non-agricultural practice caused 72.0 and 89.4% of total erosion area and soil loss respectively. As such it is important to solve the problems of erosion and/or stability arising from construction to achieve an overall reduction in the magnitude of the problems, which will be beneficial to the environment as well as to the local economy. Two ways are available to achieve this: either by way of conventional hard or ‘harsh’ civil engineering method or by way of ‘green’ or ‘bioengineering’ method.

Bioengineering, or strictly speaking soil bioengineering (in order not to be confused with similar term being used in medical or genetic sciences), is a relatively new sub-branch of civil engineering. It attempts to use live materials, mainly vegetation, on its own or in integration with civil engineering works to address the problems of erosion and slope stabilization. It was coined, as an inversion, after the German word, *ingenieurbiologie,* since this technique, although used over the centuries, evolved more systematically in the Germanic-speaking countries (Austria, Germany, Switzerland, etc) in the 1930’s.

In late 1980’s and the following decade, due to heightened awareness of environmental issues and availability of knowledge and parameters of plants that can aid as well lend credence to the design, bioengineering became more well-known and accepted. This is evident from a more widespread use as well as a number of conferences or workshops being organized during those periods.

7.1.1 Erosion and Stability Problems Identified

Although erosion and stability problems are fairly distinct, common usage tends to overlap, as problems are intertwined. Erosion is the natural process whereby external agents such as winds or water remove soil particles. In the tropical monsoon belt this involves rainfall which is responsible for the removal of surficial layers of about 10~60 cm depth. Over time, rills and gullies deepen and these cause slopes to over steepen, thus precipitating instability. Instability or deep-seated problems can arise on their own depending on slope geometry, inherent soil strength, and ground water characteristics. These are basically geological/geotechnical problems that have to be addressed by proper studies and analyses.

With a variety of computer programs available, the evaluation of the stability of slopes to determine their 'factors of safety' against sliding or failures has now become less tedious or laborious. On the other hand, shallow-seated problems, which lie in the 60-250 cm depths, do not lend themselves for such accurate computation with available software. They present a chronic problem in the tropics with the attendant heavy rainfall and inherent highly erodible slope materials. However, it is believed this problem can be dealt with very effectively by bioengineering measures which will be described in subsequent sections.

7.1.2 Vegetation for Erosion Control and Slope Stabilization

Over the millennia, Nature has 'designed' vegetation as a means to blanket and stabilise the good earth. In the tropics this has evolved into rainforests comprising complex multi-strata canopy, from big trees, shrubs and leaf litters, covering the organic humus-rich top soils, which offer excellent overall protection. In the light of current awareness and conscientiousness of environmental issues, the preferred option to address the above problems would be to go back and seek solutions that Nature has already provided in the first instance. That is, to reinstate those areas ravaged by human beings by way of re-growing vegetation. The methods of sustainable revegetation have to be studied and applied where appropriate for the problems at hand as described below.

7.1.2.1 Control of Surface Movement by Grassing and/or Leguminous Cover Crops

The use of grasses and/or leguminous covers for surficial protection is common in civil engineering or infrastructure works. In fact, it is stipulated in most standard specifications. The methods popularly employed are by seeding (manual or hydro-seeding) and turfing/sodding.

Turfing is generally carried out using local grasses. Turfing is traditionally the best method as it gives instant coverage. However, due to various extraneous factors, such as heavy demand, lack of good nurseries, labour shortage; it is being overtaken by hydro seeding on projects requiring mass production.

Hydro-seeding and turfing is successful in areas where the soil is not highly erodible (i.e. it has some cohesion) and it is not carried out in the midst of a heavy monsoon period. But its drawback is that it offers only surficial protection as shall be described in the next section.

7.1.2.2 Mitigation of Shallow-Seated Instabilities (Shallow Mass Movement) by Shrub and Tree planting

Although grass can provide effective slope protection (when soil/climatic conditions are not extreme), its roots do not extend deep enough into the soil (generally in the order of 20~40 cm) to provide the grip and anchorage needed to prevent surficial slip in the event of heavy, prolonged rainstorm. The residual soils in the tropical region with little or no cohesion, once subject to fines (soil particles whose sizes are smaller than 74 microns) being washed out by rainwater will see the collapse of the soil structure and thus liquefaction or soil flow. On many highways one can often see random patches of stone pitching, gunite shot Crete/cement spray) which are conventional rectification work carried out for the shallow-seated or shallow mass movement problems. It is not unusual to see a repeat of these repair works if the real root cause of the problems is not identified and solved accordingly.

7.1.2.3 Erosion Control and Slope Stabilization by Vetiver Grass

Unheard of by most people up to the early 80's until being actively promoted in the agricultural sector by Sir Richard Grimshaw, then of the World Bank; vetiver grass had actually been used a few centuries earlier in India. When Indians moved overseas, vetiver was brought along with them to new localities, thus explaining the presence of vetiver on various parts of the globe.

To assess the properties of vetiver for potential engineering usage, the author has conducted some experiments to do just that. Four trial embankments were constructed and planted with vetiver in August 1993 for the purpose of observing its field performance. Three months after planting, an exceptionally heavy monsoon hit the site, which caused numerous failures along major highways and hillside development projects. It was found that slopes planted with vetiver grass were not significantly affected although some slopes in the vicinity failed.

In mid-April 1994, an excavation exercise was conducted to determine the rooting depth of vetiver. It was found that the massive root networks had reached a record depth of 3.6 m after 8 mos. of growth. Other conclusions drawn from this trial included: vetiver could grow rapidly to form a complete hedgerow which managed to trap wash-off soil material; from rooting depth monitoring exercise, it was evident that the roots managed to penetrate the harder stratum (with fragments of rocks).

They not only grew vertically, but some seemed to incline themselves, following the side slope profile. From the limited trials carried out, results appeared encouraging and promising indicating the tremendous potential of vetiver for slope protection and stabilization work.

In response to a number of engineers' call for more parameters for a wide range of vegetation categories, so that they can plug them into elegant mathematical formulae in their designs, the author and his colleague decided to carry out some experiments to include vetiver among the list of vegetation with available parameters. One of the experiments involved tests on gain in shear strength in soils by the presence of vetiver roots versus identical soils which are root-free. By conducting large-scale direct shear tests at an embankment at varying depth levels, the increase in shear strength can be determined. It is also important to determine the root tensile strength properties in the process of evaluating a plant species as a component of slope stabilization. This is because when a plant root penetrates across a potential shear surface in a soil profile, the distortion of the shear zone directly resists shear while the normal component increases the confining pressure on the shear plane.

For the determination of root tensile strength, mature root specimens were sampled from 2-year-old vetiver plants grown on an embankment slope. The specimens were tested in fresh condition, limiting the time elapsed between the sampling and testing to two hours maximum. The un-branched and straight root samples about 15-20 cm long were connected vertically to a hanging balance via wooden clamp at an end while the other end was fixed to a holder that was pulled down manually until the root failed. At failure, the maximum load was monitored.

The tensile strength of root is defined as the ultimate root tensile force divided by the cross-section area of the unstressed root (without bark, as it has weaker strength properties). It was found that the mean tensile strength of vetiver roots varies from 180 to 40 MPa for the range of root diameters 0.2-2.2 mm. The mean tensile strength is about 75 MPa at 0.7-0.8 mm root diameter which is the most common diameter class for vetiver roots. This is approximately equivalent to 1/6th (one-sixth) of the tensile strength of mild steel. Compared to many hardwood species, the average tensile strength of vetiver roots is very high. Even though greater tensile forces are required to break hardwood roots, their average root tensile strength values are lower than that of vetiver because their average root diameter is higher than the 0.7-0.8 mm average diameter of vetiver roots (Table 1).

Moreover, because of its dense and massive root system underground, it offers better shear strength increase per unit fibre concentration (i.e. 6-19 kPa per kg of root per m^3 of soil) compared to 3.2-3.7 kPa/kg per m^3 of soil for tree roots. With the above results, one can say that vetiver roots behave like 'living' soil nails or soil dowels that are now being widely used for steep slope stabilization processes. The difference is that there should not be any concern over long-term corrosion prospect of metallic nails to worry about. On the contrary, 'living nails' even improve with the passage of time.

Table 5: Tensile strength of roots of some plants

Botanical Name	Common Name	Tensile Strength (MPa)
Salix spp.	Willow	9-36*
Alnus spp	Alders	4-74*
Pseudotsuga spp.	Douglas fir	19-61*
Acer sacharinum	Silver Maple	15-30*
Tsuga heterophyllia	Western Hemlock	27*
Vaccinum spp.	Huckleberry	16*
Hordeum vulgare	Barley grass,	15-31*
	forbs	2-20*
	moss	2-7kPa*
Populus spp.	Poplars	5-38*
Vetiveria zizanioides	Vetiver	40-120 (average 75**)

* After Wu (1995) ** After Hengchaovanich and Nilaweera (1998)

Studies in Malaysia reported that compared with bare soil, vetiver was able to control runoff and eroded soil (soil loss) to 73 and 98% reduction, respectively. Under field simulated rain, studies in Venezuela suggested that votive could reduce soil loss and runoff substantially as compared to the control treatments using other vegetative barrier. It is noteworthy to highlight the fact that the hedgerow adjusts itself in tandem with trapped silt on the upslope, thus ensuring that it will never get itself buried and die off.

As such, the remark of His Majesty the King of Thailand, made a few years ago that vetiver is a "living wall" is indeed very illustrative and enlightening from the bioengineering perspective. One can visualize that while the above-ground ‘wall’ caters for erosion control, the underground ‘wall’ (i.e. roots) simultaneously enhances slope stability.

7.1.3 Bioengineering Applications of Vetiver

The scope of applications are varied and many, it really leaves to the imagination what one wants to utilize vetiver, provided of course that the properties or attributes of vetiver are well understood. To sum up, these can be categorized as follows.

7.1.3.1 Slope Stabilization

This is where vetiver excels because of its long roots. As such, it should ideal for helping stabilizing cuttings and fills on highways, railways and dams. Highway bridge approaches are good locations to try vetiver bioengineering. Highly erodible and unstable slopes where shotcrete/gunite slopes are normally used can be substituted by vetiver aesthetically at lower costs.

7.1.3.2 Erosion and Gully Control

Because of its good roots and dense, stiff stems, vetiver can be used to reduce water velocity and trap sediments on highly erodible soils, gully locations to stabilize the spots in question. It can manage to grow well on very sandy soils. Vetiver planted near river or pond banks can trap the amount of silts that will flow in to make the water dirty and murky, plus the reduction in dredging maintenance costs.

7.1.3.3 Demarcation

Property boundaries or filled-up lands with or without structures can be stabilized with vetiver to keep their sitting structures intact. In tropical Australia, concrete dyke barriers at road shoulders are replaced with vetiver rows. This allows controlled low velocity flows down the roadway slope to support its revegetation. It also helps direct large flows to the outfall chutes.

7.1.3.4 Flow Diversion

Although vetiver will not be not be as good as concrete or hard barrier, but its green and relative effectiveness, cheap costs will be help divert and slow down areas where the sheet flows or flooding can harm the end-of-flow line objects or lands.

7.1.3.5 Transition Surficial Protection System

In many instances, especially river bank or river bed protection, gabion or mattresses have to be specified because of high velocity flow which vetiver alone cannot cope with. Moreover, the transition zone between the area protected by the ‘hard’ structures and the unprotected soil part is generally highly vulnerable. Other examples: strips between drain chutes, along the edge of concrete drainage channels, bridge or culvert wing walls, etc.

7.1.3.6 Vetiver as a Pioneer Species for Revegetation Projects

It has been demonstrated in several countries that vetiver when planted on slopes produced favourable ‘microclimate’ that helps enhance the establishment of other larger trees that are intended for the project.

7.1.4 Tips in the Utilization of Vetiver for Bioengineering Purposes

To derive the maximum benefits in the utilization of vetiver, one must realize that vetiver, as a living plant, is being called upon to perform engineering functions. As such, it too should be considered in an ‘engineering context’, either on its own or to supplement civil engineering works in the bioengineering measures.

To start with, vetiver system must be used with a proper design, with the designer knowing the merits and the limitation of the system and to design his engineering works accordingly. Secondly, as ‘an engineering material’, it too must be subject to some specifications and enforceable control procedures before it can be used on the ground.

Since there are some cross-disciplinary works involved, it is suggested that engineers who feel they seriously need advice on agricultural techniques should seek the guidance or get the agriculturists involved in the process of securing good planting materials, correct planting techniques and maintenance procedure in order to ensure proper establishment and long-term sustainability.

7.2 PHYTOREMEDIATION

Phytoremediation (Greek: **phyton** = plant; Latin: **remedare** = remedy) is the use of plants and trees to clean up contaminated soils and water. It is an aesthetically pleasing, passive, solar energy-driven clean-up technique. It can be used along with or, in some cases, in lieu of mechanical, chemical or thermal methods. This ‘green-clean’ technology is very popular in the United States nowadays, not only because it is environmentally friendly, but because it costs around one-tenth to one-third of the conventional remediation technologies. It is expected that in the U.S. the use of phytoremediation techniques will increase more than ten-fold in the next few years. For the rest of the world it is likely that this trend will also be followed.

Phytoremediation takes advantage of plants' nutrient utilization processes to take in water and nutrients through roots, transpire water through leaves, and act as a transformation system to metabolize organic compounds, such as oil and pesticides. Or they may absorb and bio accumulates toxic trace elements including the heavy metals, lead, cadmium, and selenium.

Phytoremediation is an in-situ approach, not reliant on the transport of contaminated material to other sites. Organic contaminants are, in many cases, completely destroyed (converted to CO2 and H2O) rather than simply immobilized or stored.

The establishment of vegetation on a site also reduces soil erosion by wind and water, which helps to prevent the spread of contaminants and reduces exposure of humans and animals.

Constructed wetlands are also considered one of the phytoremediation techniques. Constructed wetlands planted with reeds have been used to remove polluting substances from discharges from mine for quite some time before the phytoremediation as we know it today comes into vogue. Presently a variety of other plants are being investigated for used in the wetland situation.

Phytoremediation applies well for very large sites with relatively low contents of organic nutrients or metal at shallow depths and will take relatively longer time for treatment. For very high pollution levels, conventional or other methods may have to be resorted to but at a much greater cost.

7.2.1 Plants used in Phytoremediation

Plants intended for phytoremediation purposes should meet the following criteria:

- Depth of root zone,
- Growth rates and yield,
- Potential to evapotranspirate groundwater,
- Degradative enzymes production, and
- Propensity to accumulate and ability to tolerate contaminants.

Being a relatively new discipline, the list of plants that can be used for phytoremediation is still limited but now this list keeps expanding as more investigations are carried out.

Among the plants which have been tried and tested for various situations are:

Table 6: Tensile strength of roots of some plants

Plant	Situation
Poplar Trees	Used in the absorption of pesticides
Indian Mustard Grass	Accumulates selenium, sulfur, lead, chromium, cadmium, nickel zinc and copper
Tomato	Absorbs lead, zinc and cadmium)
Bamboo	Accumulates silica in its stalk and utilise it as crude protein in its leave
Sunflower	Absorbs radioactive materials such as uranium, cesium and strontium-made famous in the clean-up of post Chernobyl nuclear reactor disaster
Duckweed	For explosive waste
Willow	For hydrocarbon
Fescue, Ryegrass, Bermuda Grass	For petroleum products
Water Hyacinth	Uptakes lead, copper, iron and mercury

7.2.2 Vetiver as a Phytoremediation Plant

An obscure plant until introduced and promoted actively by the World Bank through the relentless efforts by Sir Richard Grimshaw then serving with the Bank during the late 1980's, vetiver initial usage was mainly focused in the agricultural sector. As it later became better known, the scope of its applications has been explored and greatly expanded after its unique characteristics have been determined. Vetiver lends itself ideally to engineering and environmental protection functions, hence touted as 'miracle grass', wonder grass, super grass or multi-purpose grass etc. Among its many unique characteristics are:

- It possesses seeds that are sterile, thus is non-invasive and will turn to weeds
- It grows upright and, with its stiff stems, is able to form a dense hedge within 3-4 months, resulting in the reduction of rainfall runoff velocity, and formation of an effective sediment filter. The hedgerow can adjust itself in tandem with trapped silt by forming new tillers from nodes on the culm of higher branches. It also possesses substantial biomass.
- It has a vigorous, massive and strong root system that penetrate vertically to 2-3 m depth in a year, depending on soil types. The strength of the roots has been determined to be about 75 Mpa or 1⁄6 th of mild steel.
- Tolerance to extreme climatic variation such as prolonged drought, flood, submergence, and extreme temperatures from –15 to 55ºC.
- Tolerance to a wide range of soil acidity and alkalinity (pH from 3.0 to 10.5).
- High level of tolerance to high levels of soil salinity, sodicity and magnesium.
- Highly tolerant to Al, Mn, As, Cd, Cr, Ni, Cu, Pb, Hg, Se and Zn in the soils.
- Highly efficient in absorbing dissolved N, P, Hg, Cd and Pb in polluted water.
- High level of tolerance to herbicides and pesticides.
- Although extremely versatile and hardy as above, it is intolerant to shade.

When one examines the above attributes vis-à-vis the criteria of a phytoremediation plant as cited earlier one would see that it is a promising candidate for phytoremediation purpose.

Researches in Australia over the last six years confirm the following quantitative figures on levels of tolerance by vetiver.

Table 7: Levels of tolerance of Vetiver

Heavy Metals	**Thresholds to plant growth (mg/kg)**		**Thresholds to Vetiver growth (mg/kg)**	
	Hydroponic Levels	**Soil Levels**	**Soil Levels**	**Shoot Levels**
Arsenic	0.02-7.5	2.0	100-250	21-72
Cadnium	0.2-9.0	1.5	20-60	45-48
Copper	0.5-8.0	NA	50-100	13-15
Chromium	0.5-10.0	NA	200-600	5-18
Lead	NA	NA	>1 500	>78
Mercury	NA	NA	>6	>0.12
Nickel	0.5-2.0	7-10	100	347
Selenium	NA	2-14	>74	>11
Zinc	NA	NA	>750	880

Tests have been conducted to find out the manner of distribution of the heavy metals in the roots and shoots as tabulated in Table 2 below:

The significance of this finding is that As, Cd, Cr, and Hg move up very little to the shoots, while some 1/7 to 1/3 of Cu, Pb, Ni and Se are translocated to the shoots. For Zn it is evenly distributed (40%) between shoots and roots.

Table 8: Threshold levels for potential soil contamination

Substance	Thresholds (mg kg-1)		CHEM†
	Environment*	Health*	Unit
Inorganic			
Antimony	20		
Arsenic	20	100	30
Barium			400
Cadmium	3	20	3
Cobalt			50
Chromium 6+			25
Total Cr	50		250
Copper	60		100
Lead	300	300	200
Molybdenum			10
Manganese	500		
Mercury	1		2
Nickel	60		100
Selenium			20
Sulfate	2000		
Tin	50		50
Zinc	200		500
Organics, etc.			
CN (free,total)			25
CN (complex,total)			250
Mono aromatic Hydrocarbons			7
Poly armatic hydrocarbons		20	20
Phenols			5
PCB's			1
Gasoline (C5-C10)			
Kerosine (C10-C16)			100
Oil (C17 _)			1000
Dieldrin	0.2		
Benzo (a) pyrine		1	1

*Australian and New Zealand Environment and Conservation Council/National Health and Medical Research Council
†Chemical Hazards and Emergency Management (CHEM) unit

7.2.3 Application of Vetiver in Phytoremediation

Two approaches are being made to make use of vetiver in phytoremediation, namely: (i) Reclamation of degraded Soils, and (ii) Rehabilitation of Contaminated Soils and Water. The former includes all naturally occurring deteriorated soils such as saline soil, acid sulfate soil, skeletal soil, sodic soil, sandy soil, mangrove soil, shallow soil, and steep slope land. The latter include all manmade contaminated soils and water such as garbage landfills, mine tailings, industrial waste dumping areas, effluent disposal from aseptic tanks, effluent from piggeries, cattle and poultry farms, purification of polluted water, algal growth in the river and reservoir. Each approach will be treated separately in the sections below.

7.2.4 Vetiver in wetland applications

The Latin name of vetiver is Vetiveria zizanioides. 'zizanioides' means along river banks, which connotes its riverine origin and water affinity making it a suitable wetland plant.

As mentioned earlier, reed (Phragmites spp.) beds have always been used successfully in a wetland system for quite some time such as the removal of pollutants from discharges from abandoned mines in Wales, United Kingdom.

However, it was reported that reeds could not tolerate certain chemicals such as Atrazine and Diuron from discharges of sugarcane farms in Australia while vetiver was not affected.

7.3 RECLAMATION OF DEGRADED SOILS

Degraded soils are soils which possess poor physical and chemical properties as the result of natural phenomena. Such soils are unproductive, giving poor yields to crops grown on them even with proper agricultural practice such as providing fertilizer, irrigation and pest control. They are normally referred to as problem soils, including: (1) saline soil, (2) acid sulfate soil, (3) sandy soil, (4) soil with hard pan, (5) vertisols soil, (6) peat soil, and (7) skeletal soil. In addition to these naturally-caused deteriorated soils, crop yields are also low if fertility and moisture are not adequate. Improper land management also contribute to poor yield as the result of degradation of soil properties, especially in the decline of organic matter.

7.3.1 Major Degraded Factors

The major sources of land and soil deterioration are the low fertility and poor potential fertility, affecting most highland soils and the strongly leached soils on the slightly higher terrain. These soils are all acid, with limited base saturation, and tend to have low Cation Exchange Capacity (CEC). Thus not only are natural levels of most nutrients low but the high acidity and poor CEC mean that amendments using fertilizers are difficult and require care. The other widespread soil limitations are shallow depth, lateritic gravel, the fertility problem and the liability to loss of applied nutrients during the wet season, especially on steep slopes. In addition they reduce the total water-holding capacity of the soil profile, limit rooting depth, and increase the erosion hazard and impact.

There are also a number of more specific soil constraints such as salinity and alkalinity, acid sulfate soils, coarse-textured sandy soils, result in very poor physical and chemical characteristics. Among the important deteriorated soils in Thailand are the followings:

1) Saline soil
2) Sodic soil
3) Acid sulfate soil
4) Soil with hard pan
5) Lateritic soil

7.3.2 The Use of Vetiver to Reclaim Degraded Soils

Due to population pressure and the need for land for agricultural activities, degraded soils are being reclaimed through the use of vetiver, which is found to be the most effective and low cost. Vetiver is known as a pioneer plant by agronomists. It is a species with extremely strong reverse resistance, including saline and alkaline, damp, drought, infertility and heat. These are described below:

7.3.2.1 Saline Soil

Saline soils are soils which contain excessive levels of soluble salts for the growth of most conventional crops.

The Phikun Thong Royal Development Study Centre in Narathiwat, southern Thailand has planted vetiver to stop brackish water. The grass grows well and effectively holds the soil. This usage leads to the extension of vetiver to schools and farmer housing.

The study of the effects of salt tolerant on vetiver growth has also been conducted in Chanthaburi and Chachoengsao provinces. The results indicated that at salinity levels between 0-10 mmhos, all ecotypes under trial can survive. As the salinity level increases, the grasses begin to die. When the salinity level reaches about 20 mmhos, only salt tolerant ecotypes can survive (sea water has a salinity of 40-50 mmhos). The ecotypes found to be salt tolerant are from ‘Nakhon Phanom’, ‘Kanchanaburi’, ‘Udon Thani’, ‘Ratchaburi’, and ‘Prachuap Khiri Khan’; and all are V. nemoralis.

Lowering water table is the most effective means of reducing dry land salinity. With its salt tolerant ability and deep rooting characteristics, vetiver has been successfully used to control soil erosion and at the same time lower the saline water level in south eastern and Western Australia.

7.3.2.2 Sodic Soil

Sodic soils are soils that contain excessive levels of exchangeable sodium (relative to the total salt concentration in the infiltrating water) for crop production. Contrary to saline soil, sodic soils may have much reduced permeabilities and poorer tilth. This comes about because of certain physical-chemical reactions associated, in larger part, with the colloidal fraction of soils that are primarily manifested in the slaying of aggregates and the swelling and dispersion of clay minerals.

Since 1965, the National Botanical Research Institute, Lucknow, UP, was a pioneer in using vetiver for ameliofration of sodic soils. However, it is only recently, after 40 years, that vetiver has again been opted for large-scale trials under the World Bank Program in the state. High concentration of salts in the root zone of soil limit the productivity of 950 million ha of otherwise productive land around the world. In India alone, there are 8.1 million ha of sodic land where productivity is limited. Behl and Singh (1998) were able to grow vetiver successfully in the soils with high levels of exchangeable sodium in the root zone with high pH (9 to 10.6) throughout the profile, poor water intake, occasional anaerobic stress due to water logging, poor availability of phosphorus that limits the growth, and low fertility.

7.3.2.3 Acid Sulfate Soil

Acid sulfate soils (ASS) are soils that occur on the low lying coastal areas with brackish sediments. Their natural drainage is poor or very poor, and if they have not been artificially drained, the water table lies close to or at the surface, and sometimes throughout the year. ASS constitutes a major component of arable lands in many tropical countries in Africa and Asia such a Thailand and Vietnam where rice is the main food crop. These soils are highly erodible and difficult to stabilize. Eroded sediment and leachate from ASS are extremely acidic. The leachate from ASS has led to disease and death of fish in several coastal zones of eastern Australia.

Vetiver has been successfully used to stabilize and reclaim a highly erodible ASS on coastal plain in tropical Australia, where actual soil pH is around 3.5 and oxidized pH is as low as 2.8.

As there is vast area of ASS in Thailand, there has been a great effort in reclaiming and improving such soil by using vetiver (Muensangk 2000) who did the experiment on the use of vetiver to reclaim ASS on Bang Nam Prieo soil series (P-Iia, Typic Tropaquepts) under greenhouse condition. He concluded that the 'Sri Lanka' ecotype exhibited the highest plant height and produced the highest number of tillers/hill. There was no statistical difference on plant height from using every rate of 15-15-15 fertilizer. He was of opinion that the vetiver system reclaimed ASS by retaining the runoff as a means of moisture conservation, gaining 60% of the rainfall to run off vetiver system's moisture conservation. He concluded that "This is the best way of recharging ground water".

7.3.2.4 Soil with Hard Pan

Planting of vetiver in compact hard pan and poor soil at Huai Sai Royal Development Study Centre, Phetchaburi Province to study the development of the roots system revealed that vetiver can penetrate hard pan layer of soil. This is verified by digging a vertical soil profile and using water from a hose to wash off soil particles to exhibit the amount of roots in both the topsoil and hard-panned layers. It can be concluded that vetiver roots could break through the hard-panned layer as numerous roots were found in the hard-panned layer. A break through indeed.

7.3.2.5 Lateritic Soils

The Huai Hong Khrai Royal Development Study Center has carried out experiment on vetiver planted in lateritic soil to test the growth and survival rates of 14 ecotypes. The results suggested all 14 ecotypes under study can grow moderately well and are able to survive through the dry season.

7.4 REHABILITATION OF CONTAMINATED SOILS AND WATER

One of the causes of environmental degradation is pollution due to the presence of pollutants in soils and water. The extent of the pollution in both the developing and developed countries is quite significant owing mainly to uncontrolled discharge of pollutants from various sources, including chemical by-products, heavy metal and other industrial wastes, pesticides, and fertilizer residues, domestic garbage and landfill leachate, etc. into the environment. Such environmental degradation has been a major concern for the public and private environmental agencies worldwide.

Various control measures have been attempted, but their high cost is a major drawback, especially in developing countries. Thus there is clearly a need to seek certain low-cost technology, such as phytoremediation, to deal with the ever-increasing levels of pollution.

7.4.1 Rehabilitation of Contaminated Soils

7.4.1.1 Treatment of Mining Spoils

In many countries of the world with mining activities, proper treatment of mining wastes to contain the degree of toxicity and to improve the environment at and surrounding the sites have received much attention due to enforcement of environmental regulations. However, the use of vegetation in the recent past was not too successful due to the very hostile soil and ambient temperature conditions of those sites until the breakthrough in vetiver applications. In South Africa, vetiver managed to rehabilitate the tailings of several diamonds, gold and platinum mines where other plants initially could not grow due to very high temperature (40-50ºC).

In Australia, vetiver has been successful in rehabilitating tailings of coal, bentonite and gold mines. In China, it has been experimented on a lead mine and being used on a copper mine.

7.4.1.2 Treatment of Landfills or Garbage Dumps

Landfills or garbage dumps contain varying degree of toxic materials. Experimental trials using vetiver have been carried out for an old landfill site in Australia and an urban garbage dump in Guangzhou, China.

In the Australian trial, it was discovered that vetiver has been able to revegetate an old landfill side slope which was eroded and bare due to inability of grasses and native species to establish there because of the toxicity present in the landfill.

Phytoremediation by vetiver succeeded in extracting the heavy metal contents and created favourable microclimate that induces subsequent colonization of other species. Vetiver planted at the toe of the landfill also sucked up the leachate which otherwise flowed toward a nearby stream course, posing considerable health risk.

In China, experiments showed that vetiver managed to survive, even thrived in the garbage dump. It was even claimed that bad odour has been greatly reduced in the process!

In Thailand, a trial was carried out at a major landfill in Kamphaeng Saen, 90 km north-west of Bangkok, where 5,000 t of garbage are being dumped daily. Planting was carried out in July 1999 during the rainy season. After four months, it was observed that the plants were able to survive fairly well, despite the leachate and toxicity normally associated with such a dump site. Field and parallel laboratory experiments are conducted at Chulalongkorn and Kasetsart Universities and still ongoing. Table 1 shows some preliminary results to date.

Table 9: Preliminary results from Kamphaeng Saen landfill site

Item	Period (Month)	Heavy Metals				
		Ni	Cr	Cu	Pb	Zn
Soils	0	16.1	32.4	16.6	16.14	62
	3	33	50	34.1	44.7	102
Vetiver Grass	0	5.3	1.4	0.92	0.85	9.4
	3	6.7	2.6	9.9	4	54

PARAMETER											
Item	pH	BOD +	COD+	Cl+	TKN +	TP+	Ni	Cr	Cu	Pb	Zn
Leachate	9.2	6,607	13,160	1,541	3,266	18.5	0.422	1.38	o.245	0.151	2.0

(+ Unit: mg/l) * Tested at the Pollution Control Department (PCD) Laboratory

7.4.1.3 Removal of Agrochemicals and Pesticides

Thailand research conducted on cabbage crops grown on steep slopes indicated that vetiver hedges had an important role in the process of captivity and decontamination of agrochemicals and pesticides preventing them from contaminating and accumulating in crops.

7.4.2 Rehabilitation of Contaminated Water

7.4.2.1 Water Purification

Vetiver was tried in China for the removal of P and N. It was found that after three weeks; virtually all P was sucked up, while 74% of N was removed. Experiments conducted in Thailand on wastewater indicated that vetiver had the ability to uptake heavy metals and accumulated in the shoots and roots. Such experiments indicated the possibility of vetiver as a biological wastewater treatment.

7.4.2.2 Remediation of Eutrophic Water

River and lake water subjected to pollution by N and P, especially P which is the key element responsible for water eutrophication exhibiting as blue green algal growth in rivers and lakes. With intensive farming adjacent these water bodies, the quantities of N and P are bound to increase. From experiments in China, it was found that vetiver can be grown along the shore or banks to first filter off the chemicals and then grown hydroponically in water along banks. The N and P were removed efficiently and the water became more transparent after treatment.

Picture 36-37: Use of Vetiver for treatment of highly polluted pond (Funafuti - Tuvalu)

7.4.2.3 Vetiver in Wetland Applications

The Latin name of vetiver is C.zizanioides. 'zizanioides' means along river banks, which connotes its riverine origin and water affinity making it a suitable wetland plant.

As mentioned earlier, reed (Phragmites spp.) beds have always been used successfully in a wetland system for quite some time such as the removal of pollutants from discharges from abandoned mines in Wales, United Kingdom.

However, it was reported that reeds could not tolerate certain chemicals such as Atrzine and Diuron from discharges of sugarcane farms in Australia while vetiver was not affected. Assuch, in some situation, vetiver may be able to perform better, depending on trial and experiments.

Picture 38-39: Constructed wetland site (Toogoolawah QLD Australia)

7.4.2.4 Vetiver for the Removal of Effluents

In the same manner of pollutant removal as mentioned in the foregoing sections, vetiver can be used for trapping P, N and other nutrients in effluent discharges. In China, it was reported on the successful use of vetiver in a piggery. In Australia, a summer camp with several lodges had planted vetiver to intercept the effluent that seeped out from a septic tank with good success.

Picture 40: Sewerage effluent pond (Goroka - Papua New Guinea)

7.4.2.5 Conclusion

As mentioned above, vetiver possesses unique characteristics that lend itself as an ideal plant for phytoremediation purposes. However, the use of vetiver in phytoremediation work is still not widespread, being pioneered in mostly limited in South Africa and Australia. Even there, many instances are test sections and some are laboratory experiments only. It is hoped that once it is better known and more people start trying it, more information will come to light that will convince people to apply it as in the case of bioengineering.

7.5 DISASTER PREVENTION, MIIGATION OR REHABILITATION

7.5.1 What are Disasters?

“A disaster can be defined as any unforeseen or sudden situation that the affected community is unable to cope with, or an event when natural hazards interact with existing conditions so that they disrupt the ability of a community to feed and care for their families. The natural hazards become disasters when the disruptions exceed the adjustment capacity of the community” (Shelton 2000).

The Pacific is one of the most disaster prone regions in the world in terms of the recurrence, severity and scope of natural hazards, with high exposure to cyclones, earthquakes, tsunamis, floods, tidal surges, landslides, droughts, forest fires and volcanic eruptions, in addition to epidemics.

7.5.2 What are the Causes of Disasters?

The primary causes of natural disasters are storms and torrential rains which often result in landslides, mudslides, flood, destruction of construction sites, buildings, orchards, etc., and even death of people.

7.5.3 Recent Disasters in the Pacific Islands

7.5.3.1 Torrential Rains in Papua New Guinea

During the first few weeks of December 1999, there was a period of heavy and sustained rainfall resulting in many landslides that destroyed areas of forest and village gardens, blocked roads and damaged houses. The only road linking two thirds of the approximately two million people population of the PNG highlands with the rest of the country and the seaports was cut and no essential supplies were able to get through until the road was cleared after about a week. This particular incidence was not a serious disaster, unlike the one which occurred in 1970 (see below), but it nevertheless caused hardship to many people (Shelton 2000).

The real natural disaster caused by very heavy and sustained rain occurred in Simbu Province in PNG in 1970. A torrent of water, rocks and debris that inundated on the people caused twelve deaths in the village. The only warning they had, and that was not much more than a minute, was the roar caused by the wall of water, estimated to be 10 m high, bearing down on them. During such a period of sustained torrential rain, rock and mudslides occurred in areas of virgin bush in the mountains above the village but remote from any other settlements. Some of these landslides blocked the river, formed an unstable dam and water was backed up behind it (Shelton 2000).

7.5.3.2 Worst flooding in Solomon Islands

The passing of Tropical Cyclone Ita at the beginning of April 2014, triggered some of the worst flooding ever seen in this vulnerable Pacific Island.

Heavy rain brought by Tropical Cyclone Ita in early April caused some of the worst flash flooding in the history of the Solomon Islands. The rains caused river systems to overflow, sending torrents of brown water through the capital Honiara and villages across Guadalcanal Province.

Homes and infrastructure were washed away including one of only two bridges linking the east and west Honiara. Aid workers reported seeing people carried out to sea, many of whom were women and children.

At least 22 people were killed and 50,000 affected – almost 10% of the country's population.

Picture 41: Flash flooding of the Mataniko River that washed away homes (Honiara - SI)

7.5.3.3 Vanuatu hit by an earthquake, a volcano then cyclone Pam

First there was the earthquake. Then the volcano erupted. Finally came cyclone Pam, one of the most powerful storms to rip through the South Pacific. It just happened within the space of just few weeks to the small Vanuatu Island of Ambrym. The storm flattened the subsistence crops they rely on for food, remarkably homes have mostly remained intact and no reported deaths (Joshua Robertson)

Picture 42: A villager in front of his damaged home (Port Vila, Vanuatu) – Picture by J Robertson

7.5.3.4 Tropical Depression Causes Floods and Landslides in Fiji

Slow moving tropical depression brought heavy rain to parts of Fiji in December (2016). Some areas recorded 500 mm of rain in 24 hours. Fijis National Disaster Management office reported that over 1,000 people were evacuated from their homes to stay in evacuation centres. Flooding and landslides caused damage to roads, farms and damaged properties. Some roads were blocked by floods and landslides, making access difficult and leaving some areas cut off (Richard Davies)

Picture 43: Flooding in Nausori (Fiji) – Picture by Richard Davies

7.5.4 Prevention of Disasters

For practical purpose, it is not possible to prevent any disasters, including landslides, mudslides, floods, or any other destruction caused by storms and heavy sustained rain on steep slopes, forested or not, particularly if the profile is already saturated and if it overlays rock or some other sort of impervious layer.

7.5.5 Mitigation of Disasters and Other Measures after the Disasters

As it is not possible to prevent disaster from happening, the best we could do is to mitigate them or putting measures to reduce damages caused by these disasters in the future. Among those found to be most practical is the use of the vetiver system.

7.5.6 Discussion

It seems that recent disasters have been far more deadly than it used to happen. The reason for such devastating act of nature is because of the destruction of forests and wetlands that act as "buffer" systems diminishing the surface runoff, and because flooding was aggravated by a lack of adequate watershed management. People die, are injured, or lose their homes in natural disasters, because they continue to build and live in unsafe structures and in vulnerable locations. Another reason stems from social vulnerability and poverty. Poor people do not have access to arable and safe land. They have to live and farm on marginalized areas, such as floodplains and steep slopes, maximizing their exposure to the next disaster.

“VS can play a key role in disaster mitigation and vulnerability reduction. The purpose and role of VS in disaster mitigation and vulnerability reduction is to protect and conserve, not nature, but our interventions within nature and our attempts to manage nature for our own ends. VS is not and cannot be a substitute for appropriate siting of infrastructure, for avoiding encroachment into flood plains and other vulnerable areas, for halting watershed and soil degradation, in short, for overall good natural resource management and land stewardship, for common sense, and for quality designs and construction” (Smyle 2000).

8. UTILIZATION OF VETIVER

8.1 HANDICRAFT PRODUCTION

The main objective of planting vetiver is to make use of the plant in soil and water conservation, especially in slope areas. There are several other related uses of the vetiver plant such as on the farmlands, in agricultural systems, on the edges of the ponds, etc. However, planting for conservation purpose focuses on its benefits in terms of conservation which cannot be valued in terms of cash for the growers. Therefore some farmers are reluctant to accept its potential benefits.

In most Asian countries, vetiver has traditionally been utilized in many ways. The leaves, for example, have been utilized to make roof thatch, compost and mulch, etc. Its fragrant roots have traditionally been utilized to extract essential oil used as a fixative for high-priced perfumes; they have also been utilized in traditional medicines. Due to the presence of certain pesticidal compounds, its roots have been placed in the closet to repel insects. In Thailand as well as in some other countries, many new ideas have recently been added to utilize vetiver, for example, as a medium for mushroom growing, as green fuel, and as raw material for wood and concrete panels, etc. The utilization of the leaves plays a complementary role in growing vetiver for soil and water conservation purposes since the leaves are normally cut off at regular intervals to stimulate its growth. Such cut leaves can be utilized in making handicrafts as a supplementary occupation to earn extra income. The present paper will describe how to utilize vetiver leaves as raw material for making handicrafts.

8.1.1 Preparatory Steps for the Utilization of Vetiver Leaves in Handicraft Making

In making handicraft products from vetiver leaves, three preparatory steps have to be followed. These are:

8.1.1.1 Pre-harvest Operation

Vetiver leaves to be utilized for handicraft making should be at least three months old, irrespective of the age of the plant. They can come from a single hedgerow, or multiple hedgerows, or a field of vetiver planted for any other purposes, including the multiplication plots that are not used for transplanting. Normally, vetiver does not need any special care like watering, weeding, pesticide spraying, or fertilizer application. However, if such treatments are nominally provided, the leaves will be more luxuriant in growth with no sign of damage from pest attacks, and thus yield better quality products.

8.1.1.2 Harvesting of Vetiver Leaves

Sickles or knives are used to harvest vetiver leaves. Cutting should be made at the distance of 15-20 cm above ground level. Cutting lower than this (e.g. 5-10 cm) will affect subsequent growth of the plant although the yield of leaves is higher. In normal situation, harvesting can be done every two to three months during the rainy season, depending on the growth of the plant. It is important to cut the leaves off before the onset of dry season to avoid fire damage during the prolonged drought period and to activate the plant to resume growth at the onset of the next rainy season. Cutting will also stimulate tillering.

The cut leaves should be spread thinly in the field to allow water to evaporate, at least for a few hours, before they are transported to the processing area. If the fresh leaves are transported immediately after harvesting, extra weight of water will add to the cost of transportation, although this may be small if the amount harvested is not large.

Picture 44: Harvesting of vetiver leaves using knife

8.1.1.3 Post-harvest Treatment of Vetiver Leaves

There are many methods used by different agencies in Thailand in preparing harvested leaves, especially in drying; some simply spread the leaves on the floor to dry in the sun, while others use the oven to dry. The followings are steps in processing the harvested leaves developed by the Department of Industrial Promotion:

(i) Boil the leaves for 3 minutes and hang them to allow water to drip dry overnight.

Picture 45-46: Boiling the leaves (L) and leaves hanged to allow drying overnight (R)

(ii) Spread the leaves thinly on the floor to dry in the sun for 3 days.

Picture 47-48: Spreading of leaves on the floor

(iii) Fumigate the dried leaves in the cabinet overnight with sulfur to prevent moulding.
(iv) Select the leaves that are long, wide, and healthy; then use a needle to rip off sharp spines along the edge of the lower surface of the leaves.
(v) Immerse the selected leaves in the water; then wrap them with newspaper or cloth to make them soft. Such treatment makes them easy to work with, and will not break while interlacing or weaving.
(vi) Repeat Step
(vii) to make sure that mould will not attack them.
(viii) Dye the treated leaves, either with natural dyes (such as bark, leaf, fruit, etc.), or chemical dyes to make the products colourful and attractive.

8.1.2 The Making of Handicrafts from Vetiver Leaves

Similar to other natural materials commonly used in handicrafts, vetiver leaves contain high amount of fiber, thus are ideal for wicker works. They can be utilized directly to make wicker works, or interlaced into 'basic units' of different shapes and forms before setting up to form any particular wicker works, or using looms to weave into mat. Other materials like rattan, wire, rod, wood, etc. may be used to support the forms.

8.1.2.1 Direct Utilization of Vetiver Leaves

Most wicker works can be made directly from prepared vetiver leaves without having to be made into 'basic unit' (see detail below). These include a wide range of products from handy accessories, containers, decorating materials, home appliances, and miscellaneous objects.

8.1.2.2 Production of Basic Units

Two types of basic units of wicker works can be made from vetiver leaves. These include: (i) braids, and (ii) interlaces.

1) Braids

Braids are formed by twisting three or more threads of natural fibres such as vetiver leaves. Various patterns of braids have been developed by Thai people.

Picture 49-50: Braiding of leaves for handicraft making

2) Interlaced Patterns

Thai people have developed various interlaced patterns whose Thai names reflect their similarity with certain natural objects or phenomena such as flowers, seeds, animals, appliances, running water, etc.

8.1.3 Types of Handicrafts Made from Vetiver Leaves

Most handicrafts made from vetiver leaves are wicker works, made directly by interlacing the prepared vetiver leaves into a particular form of products, or made from braids or interlaced patterns without having to set up, like the place mat, pillow, etc. Some are, however, made by assembling braids or interlaced patterns to form an object by sewing or sticking with glue.

The Department of Industrial Promotion (DIP) has provided basic training in producing handicrafts to a number of women's groups under the supervision of various agencies such as the Department of Cooperative Promotion, the Department of Agricultural Extension, the Land Development Department, the Department of Public Welfare, and the Doi Tung Development Project.

Handicraft products made from vetiver leaves can be grouped under following categories:

8.1.3.1 Handy Accessories

These are the most t common group of wicker works made from vetiver leaves since the demand is quite high. These include bags, hats, belts and brooches.

8.1.3.2 Containers

This type of wicker works is used to put certain objects into it. They include:

- Basketry: Many forms, shapes, and sizes of baskets are produced, such as fruit baskets, winnowing baskets, utility baskets, wine baskets, and flat baskets or trays.
- Pottery: Such as pot-plant cases, wine-bottle case, etc.
- Other Objects: Tissue-paper boxes, utility boxes, etc.

Picture 51-52: Basket made out of vetiver leaves

8.1.3.3 Decorating Materials

Home decoration items, like wall clocks, picture frames, lamp-shades, dollies, animal figures, flowers, etc.


Picture 53-54: Decoration items made out of vetiver roots

8.1.3.4 Home Appliances

These products are similar to home decoration objects but they are used also as appliances such as chairs, stools, room partitions, tables, etc. Mats and similar objects are also produced by weaving.

8.1.3.5 Miscellaneous: Such as folders, diary covers file covers, etc.

8.1.4 Socio-Economic Considerations

8.1.4.1 Benefits of Making Handicraft from Vetiver Leaves

The following benefits are envisaged from utilizing vetiver leaves to make handicrafts:

- Earn extra income from sale of products.
- Encourage farmers to plant more vetiver and obtain indirect benefits of planting vetiver such as reducing soil erosion and enriching soil nutrients and moisture.
- Encourage farmers to cut the leaves of vetiver at regular interval, thus inducing growth of the vetiver plants and reducing the danger of fire.
- Encourage the establishment of housewife groups (or other related groups) to make productive use of their time, thereby helping the well-being of the members and encouraging their unity.

8.1.4.2 Marketing of Vetiver Handicrafts

Although at present vetiver handicrafts are not established products in the market, yet they are quite well known to the public due to their publicity through mass media. The only problem is their availability in the markets.

8.1.5 Bleaching

Naturally, fibre derived from plants, whether the stems or leaves, have their original colours, which are yellow or brownish yellow. However, to meet the demands of the market, the fibre materials for weaving have to go through dyeing process by first bleaching to have a white colour, and then dyeing to make colourful finished products

Bleaching Solutions

Chemical Substance - Ratio	Methods
▪ Bleach the fibre with H2O2 at room temperature. - H2O2: Water = 1:20 - 1:30. - Use H2O2: 20-50 cc/liter ▪	▪ Soak the fibre in water for 10-12 hours before bleaching. ▪ Clean the fibre with water. ▪
▪ Bleaching the fibre with H2O2 at high temperature (about 70-80oC) - H2O2: Water = 1:20 - 1:30. - Use H2O2: 10- 15 cc/liter and no more than 20cc/liter. ▪	▪ Boil the water at about 80oC Add H2O2 and stir thoroughly. ▪ Add the fibre and leave for 30-60 min. ▪ Take the fibre out and clean thoroughly.
▪ Bleaching the fibre with chlorine. - H2O2 : Water = 1:20 - 1:30 - Use chlorine powder: 8 - 10 g per liter.	▪ Dissolve chlorine into prepared water. Divide the water into four colours. Wait until the chlorine is sedimented, and then use the clear water. Repeat the step until all of the water is dissolve with chlorine. Soak fibre in the chlorine water for 30 min. and clean it with water. Then put the fibre in water which contains acetic acid 5 - 10%.

Table 10: Bleaching solutions

8.1.6 Colour Mixture for Dyeing

In order to have various colours of the dye, they have to be mixed to obtain desired colour. The following table provides necessary information on mixing the colour for dying:

Table 11: Colour mixtures to obtain for the dyeing

Dye colour	Colour composition	Resulting colour
Purple	Pink + Dark Blue Steps ▪ Use pink colour as the main colour. ▪ Gently add dark blue colour and stop when it turns to purple. If one w ants bluish purple, then continue adding blue colour and it will give the colour of reddish purple or bluish purple	Reddish Purple Bluish Purple
Crimson	Golden yellow + Pink Steps	

Grey	▪ Use pink colour as the main colour. ▪ Gently add golden yellow until the colour turns to crims on Dark Blue + Purple + Black Steps ▪ Use moderate quantity of dark blue colour. ▪ Add a little of the purple colour. ▪ And finally add a little of the black colour.	Light Grey
	Dark Blue + Black Steps ▪ Maintain dark blue as the main colour and add moderate amount. ▪ Add a little amount of the black colour to make it bluish grey	Reddish Grey
Green	Golden Yellow + Blue Steps ▪ Use golden yellow as main colour. ▪ Gently add dark blue until it changes to dark green.	Dark Green
	Light Yellow + Blue Steps ▪ Use light yellow as main colour. ▪ Add dark green to give a green leaf colour.	Leafy Green
	Orange + Blue Steps ▪ Use orange as main colour. ▪ Gently add dark blue to make brownish green.	Khaki Colour
Orange	Light yellow + Pinkish Red Golden yellow + Crimson Steps ▪ Use yellow as main colour and pour in first. ▪ Then add crimson or pinkish red to make orange colour	Orange
Brown	Yellow + Purple + Dark Blue Steps ▪ Use yellow as main colour. ▪ Add purple to make it brown. ▪ Add dark blue to make it dark brown. Golden Yellow + Bright Red + Dark Green Steps ▪ Use yellow as main colour ▪ Add bright red to make orange colour. ▪ Add little green to make brown colour.	Dark Brown Golden Brown
	Orange + Dark Blue Steps ▪ Use orange as main colour. ▪ Gently add dark blue to make brown colour.	Brown

8.1.7 Processes of Dyeing

These processes are explained below:

Proportions	Methods
▪ Dye water: 1 portion of fibre per 30 portions of water ▪ Dye colour: depends on the preference for dye colour concentration ▪ 2 - 4 tablespoons of acetic acid	▪ Soak the fibre for at least 6 hours before dyeing. ▪ Boil dye water at high heat or boiling slowly. ▪ Put the dye colour and stir thoroughly. ▪ Put the fibre into the boiling dye water and constantly turning it over for 5 minutes. Then remove the fibre out of the water. ▪ Add acetic acid and stir. ▪ Place the fibre back in and continue boiling the fibre for 5-10 minutes. Keep turning it over. ▪ Take the fibre out and clean with water.

Table 12: The process of dyeing

8.1.8 Natural Dyes

These are dyes present in certain plants. They can be extracted and used to dye vetiver leaves. Among the most effective and easy to find are turmuric rhizome, butterfly pea flower, teak leaf, and red cabbage. The extraction method to make 4 liters of dye solution is as follows: Obtain 50-100 g (dry weight) of plant material, boil in 4 liter of water until boiling. Remove from fire and leave it for 1 hr. Filter, express excess water and wash with hot water to obtain remaining dye in order to make 4 liter of dye solution.

Dying Process:

1. Soak prepared dry leaves in hot water (be sure to press the leaves in the water)
2. Place on low-flame fire, at 60-80oC for 1 hr.
3. Repeat steps 1 and 2 every day for 3-5 days in order for the leaves to absorb more dye.
4. Add 5 g of allum into dye solution. Boil until the allum dissolves. Continue soaking for 1 day
5. Remove the leaves from the dye solution. Wash off extra dye. Dry in the shade

.

Note: In order to make the leaves soft and not remain too brittle, add 1 table spoonful each of olive oil and hair conditioner dissolved in 3 liter of water. Soak the leaves for 3-5 minutes before weaving.

8.2 Agricultural Input and Other Related Products

The main purpose of growing vetiver is to conserve soil and water, particularly for steep slope areas. In spite of the effort, however, some farmers are still reluctant to accept its valuable attributes because the cultivation of vetiver in agricultural areas in order to conserve soil and water does not produce tangible benefits in terms of income.

Actually, vetiver leaves and roots can be used for other purposes, especially its leaves, which usually have to be cut down to the ground periodically to induce tillering and root growth as well as to avoid fire during the dry season, can be used of in various ways, particularly to produce agricultural input products which would provide the farmers with an extra income. Although essential oil also can be extracted from vetiver root, and there seems to be a high demand for such oil in perfumery business, but in order to have the oil, digging its roots is required. Such a practice is against the principle of soil conservation and of course, of VS in general.

Thus, this course will not touch on essential oil extraction or other uses of the roots (e.g. as herbal medicine and vetiver blind) as it is rather dangerous to encourage such a practice.

8.2.1 Mushroom Culturing

Vetiver leaves contain chemical compounds such as cellulose, hemicellulose, lignin and crude protein as well as various minerals which can be used as substrate for mushroom culturing. The Thai Department of Agriculture has conducted an experiment by cutting leaves and culms of vetiver into small pieces, 1-1.5” in size, and soaked them in water before allowing them to ferment for 3-4 days. Then they were packed in a bag and sterilized, using the same procedure as in mushroom spawn preparation. The content was then inoculated with different kinds of mushroom spawns. Pleurotus spp. (e.g. oyster mushroom, abalone mushroom, shiitake mushroom, etc.) are able to produce mycelium and form fruiting bodies to become the mushroom.

8.2.2 Compost

Vetiver culms and leaves, which are cut to accelerate tillering can be used to make compost similar to other crop residues. In the process of making compost, vetiver culms and leaves completely decompose within 60-120 days. Then, it will become soft, friable, and dark brown to black in colour. The analysis showed that compost made from one ton of vetiver leaves is equivalent to 43 kg of ammonium sulfate. Vetiver compost tends to gain more major nutrients such as nitrogen, phosphorus, potassium, calcium and magnesium on an average of 0.86, 0.29, 1.12, 0.55 and 0.41% respectively, with a pH of 7.0 In addition, vetiver compost provides humic acid which enhances soil fertility.

8.2.3 Mulching

Vetiver leaves are excellent material for mulching. Similar to other mulching material, vetiver leaves provides shade to the plot, thereby decreasing the temperature and at the same time conserve moisture of the plot and keep weeds under control. Vetiver mulch can be applied to vegetable plots, at the base of fruit trees, and field crop plots.

Picture 55-56: Leaves used as mulch in Vanuatu and Papua New Guinea

8.2.4 Animal fodder and feed stuff

Many small farmers and agencies that support small farmers reject vetiver because they think that it is useless as forage. This is in fact not true. If vetiver hedges are cut regularly, the forage value of the leaves is comparable to other grasses, and in drought years the only grass that provides any feed value at all is vetiver. In India vast plains of Vetiveria nigratana are burnt each spring to produce an early bite for Fulani livestock.

The Thai Department of Livestock undertook a study on the nutritive value of vetiver as animal feedstuff. The trials were conducted on ten ecotypes of vetiver with the result that Kamphaeng Phet 2 gave better nutritive value than other ecotypes in terms of quantity of crude protein, digestible dry matter, and minerals. Vetiver cut at four-week interval is optimal in terms of output and nutritive value. The study on the toxic content in the ten ecotypes revealed that vetiver has insignificant level of nitrate and hence is not harmful to animals. Furthermore, nitrate and hydrocyanic acids are not found in vetiver.

The study also looked into the nutritive values of vetiver ensilaged with various ingredients in terms of palatability, pH level, dry matter percentage, lactic acid, muteric acid, dietary value and digestibility of dry matter. It was found that vetiver silage fested in treatments with 10% molass, 15% cassava, and 0.5% urea, plus 10% molass, all have acceptable quality.

The study revealed that young vetiver leaves can be ground to feed fish and livestock feed but mature leaves cannot be used for such purposes because their nutritive value is lower than other grasses, and because of the high roughness and silica content.

The analysis also indicated that vetiver has the content of crude protein lower than that of other grasses used for animal feed.

In comparison with dried straw, vetiver has a lower dry matter percentage but higher content of crude protein and digestible fibre. Meanwhile the analysis of nutritive value of silage indicated that vetiver-based silage has higher animal nutritive value than straw-based silage, and dry straw and signal grass. The analysis of major nutrients in vetiver leaves and culms showed that they have lower phosphorus but higher potassium content when compared to sweet corn and baby corn leaves and stems.

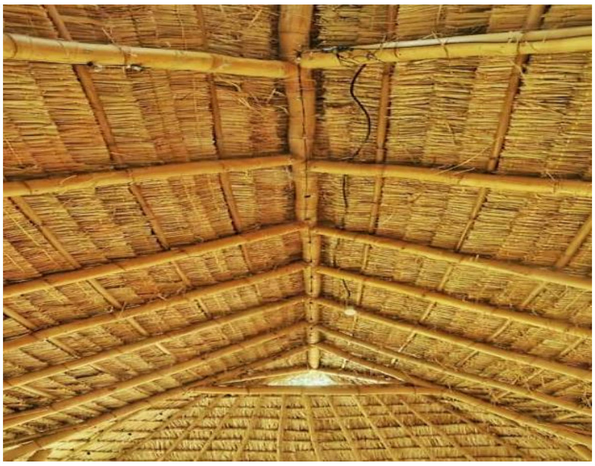
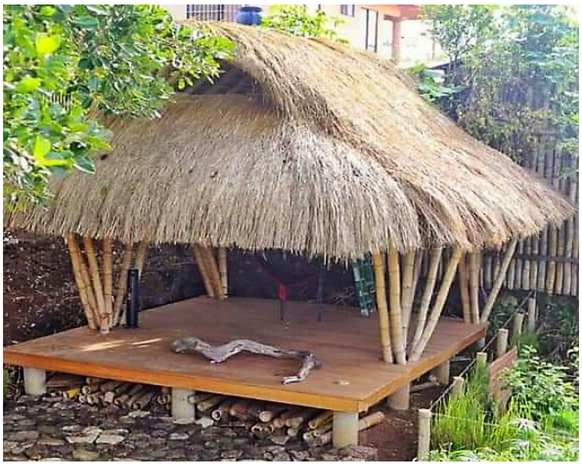

Picture 57-58: Leaves as animal feed

8.2.5 Thatching

Thai people as well as other rural people in Asia have long utilized vetiver culms and leaves for roof thatching in the same way as nipa palm leaves prior to the use of cogon grass (Imperata cylindrica) which can be easily found. Vetiver grass that will be used for making roof should be grown in a healthy condition and should be at least one year old. The leaves should turn from green to yellow, but they should not be completely dry. The leaves are normally harvested between January and February by cutting the grass at about 10 cm above ground. Then comb off short or broken leaves, leave to sun dry, and bundle into "kone" comprising about 30 handful bunches which can produce about 5 to 7 thatches.

To make each individual thatch, a piece of bamboo is used as a central column to hold the grass together. At each binding, 5-6 vetiver culms with about 12-16 leaves are folded, with one third of the broader end being on the shorter side, and the other end on the longer side, and then fastened tight to the central column with bamboo strips or other materials. Binding is done until the thatch is completed.

The laying of the thatch starts from the lower level of the roof and continues up to the top of the structure, with the shorter end of the thatch being on the underside.

Picture 59-60: Leaves as a thatch material

8.2.6 Green Fuel

Broken vetiver culms and leaves that cannot be utilized for other purposes can be mixed with water hyacinth, as a mixer, in a proportion of 3:2. Then compress the mixture into shafts with a cylinder-shaped fuel squeezer, 1.7 cm in diameter. Fuel shafts can burn easily and produce little smoke, but yield high temperature. For example, it takes 5 minutes to boil 1 liter of water, and the fuel still keeps on burning for up to 28 minutes.

8.3 THE ALTERNATIVE ROLES OF VETIVER UTILIZATION

Vetiver is now successfully applied for soil and water conservation, both inside and outside farm lands all over the world. Low cost investment and simple technology would encourage more and more widespread customers in the near future. Natural resources and environmental impact area also manoeuvrable by vetiver hedge systems.

8.3.1 Vetiver: Crop of Maintenance

- Pilot project model
- Farm production demonstration
- Project cottage industry plant test for:
    - Decorative products
    - Pulping paper and related products
    - Grain size demonstration units

8.3.2 Marketing

- Marketing promotion.
- Consumer attitude.
- Sales planning and strategy.

8.3.3 Vision

A better understanding related to the function of Vetiver Hedge System. Products would provide a lot of benefit to be maintained in the near future for the environments and natural resources.

9.0 THE CONCEPT OF VETIVER ETENSION AND PROMOTION

9.1.1 Introduction

Agricultural development visualizes production as a source of income and the most important work for the countries which depend on agriculture with the majority of the people engaged in farming. Agricultural practices have been developed since the demand of food is increasing with the increase of world population. Agricultural development means changing for better production by the use of new varieties and/or new systems with appropriate use of resources. Farmers will learn how to produce maximum yield for better income and better quality of life. Agricultural development should include the following elements:

9.1.2 Research

Research is one of the important elements of the development. Research for new technology in agriculture will enable the farmers to grow better crops with better production technology, and obtain better income.

9.1.3 Agricultural Input

Whenever farmers grow some crops, the input supplies such as seed, fertilizer, water, pesticide and management will maximize the output.

9.1.4 Infrastructure

Infrastructures assist agricultural development. These include market place, feeder roads, communication, retail outlets of input, and credit and loan. In order to have better development, all of these infrastructures have to be available and promoted.

9.1.5 Farmer Incentives and Agricultural Price

These elements have played an important role that makes farmers interest and practice. What they expect are good price and good income. Farmer’s incentives come from the attention and good care of the extension officials. Close relation and close advice will make farmers happy and satisfied.

9.1.6 Land Development

At this moment, land and soil on highland for development have serious problems because of the changing in soil fertility and increasing use of the land that causes land degradation.

9.1.7 Agricultural Extension Education

Agricultural development could not exist without the knowledge of the farmer development. Agricultural extension education is the most important element of the whole development process because the farmers learn from these elements and practice in appropriate way with their basic or indigenous knowledge that makes better agricultural development. The success of agricultural development does not aim only to maximize production, but it must improve the quality of life of the farmers. Quality of life is different from one country to another, and from one culture to another as well. The common understanding on this issue is how the people in the rural area can live with food security, healthy and in better environment. Farm family becomes the focus of the development; so family has to be in the good community.

Agricultural development on the highland is no exception. These elements of development need to be prepared and carried out in or der to make agricultural development most successful and sustainable.

9.2 Agricultural Extension Education

Agricultural extension is one of the essential and most important elements in agricultural development. Agricultural extension education is the process that can change the behaviour of the farmers to know, to learn, and to adopt new technologies or innovations for their agricultural practices. The process of the learning is mostly done in the informal way in which the farmers can learn by doing. Agricultural extension consists of three processes, viz.:

9.2.1 Education Process

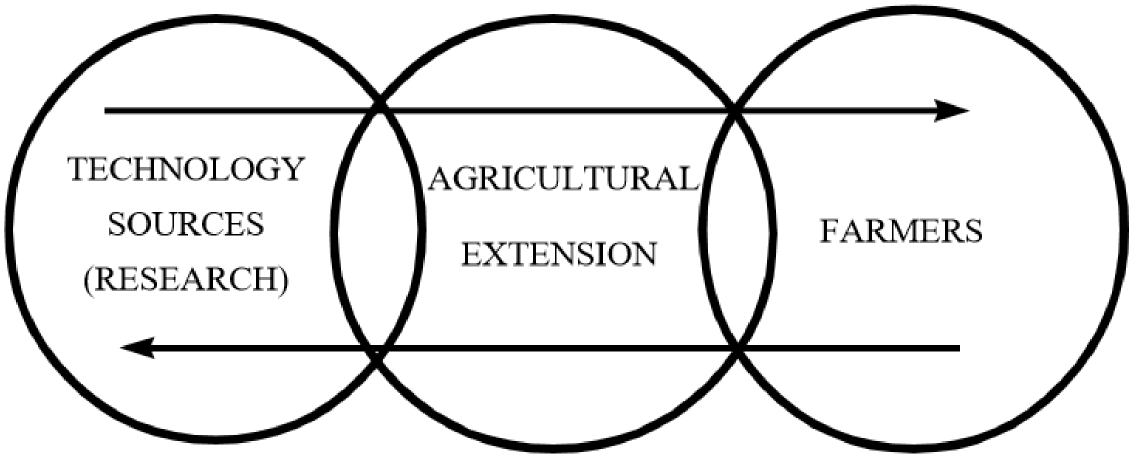
The objective of agricultural extension is to change the behaviour of the farmers to adopt the innovation. Then, the behaviour can change when the learning process is taking place. But education in this process is mostly done by the pattern of informal education because it is easy for the farmers to learn without any limitations, and especially through the method of ‘leaning by doing’.

9.2.2 Continuous Process

The development of the knowledge for the farmers must be turning around and changing due to the change of the technologies and methodologies of new agricultural practices. Farmers have to learn from one situation to another, and keep on learning. Then, the development will change from time to time, and from the better to the best.

9.2.3 Democratic Process

Farmers will accept the innovation and use it with their own consideration and decision. They are happy to adopt the new technologies or new system. Whenever they consider that it is appropriate to the own capability and with their own satisfaction. Participating in the living process of the farmers is considered as high as the farmers can. Then the technologies or the methods that they adopt will be more sustained. Agricultural extension education is the bridge that links between the knowledge from the research output to the farmer practices.



Source: *Angkasith (1995). Supervision in Agricultural Extension, p.28.*

Fig. 2. Extension linkages from research to farmer: System that exists and mostly used in the underdeveloped countries.

9.3. Scope of Agricultural Extension Responsibility

Agricultural extension education has specific mandate in which extension workers have to perform and be responsible. These include:

9.3.1 Agricultural Production

The main responsibility of agricultural extension education is to increase production that can make better income for the farmers and to maintain good natural resources.

9.3.2 Marketing Distribution and Utilization of Farm Products

Agricultural production can be subsistence, semi-commercial and full-commercial. Marketing system and production price of whatever crops the farmers are growing have to be carefully considered. Farm products have to utilized in terms of value added and agro-industrial purpose.

9.3.3 Conservation and Development of Natural Resources

At present, natural resources seems to be the most important element to all people who are involved in agricultural development. During the past three decades, the world had enough resources to support agricultural practice. Now it has less, and the use of natural resources becomes inappropriate. This causes soil degradation, shortage of water, and especially pollution (through the use of chemicals to increase production). Extension workers have to take serious consideration and have to advice and provide strong recommendation to the farmers to practice agriculture in the proper way.

9.3.4 Management on Farm and House

Agricultural production becomes economical oriented. Farmers have to learn how to keep their farms and houses in better condition. Farmers have to manage investment and make a profit that can bring better income.

9.3.5 Family Living and Farmer Quality of Life

The ultimate goal of the people is to have good quality of life and family living condition. Farm family is a goal for the farmers; they have to have better income, be in good health, with good education, enjoying safety of life, and live in good environment. Extension workers have to teach the farmers on how to arrive at these conditions.

9.3.6 Youth Development

The future of agricultural development is in the hand of young people (young farmer). Extension work has to plan for the future of agricultural development. Young farmers who will take an important job for the future have to be prepared; they have to be informed, trained, and educated in the new agricultural system so that their farming can be sustained.

9.3.7 Leadership Development

Extension needs leadership for the future of agricultural development. Extension workers and farmers should have a vision for development in the future which will lead to the success of these wishes.

9.3.8 Community Improvement and Resources Development

Farm family is the base of the community; thus its improvement and resource development must be in the proper way.

9.3.9 Public Affairs

Extension work always involves in public affairs, especially the community where farmers live. Farm families have to support the public affairs such as cultural activities and public development.

9.4 Principle of Agricultural Extension Education

Generally speaking, every work has to have the principles which will be the foundation for activities of the job. Agricultural extension education, also have principles, viz:

9.4.1 Educational Service

Agricultural extension is an educational service. Extension education develops the knowledge of the farmers in agricultural practices by using technologies for better production. Farmers have to learn from the real situation and by doing.

9.4.2 Based on Farmer's Situation

Extension education has to educate the farmers from what they are, and how they operate the farm. In introducing new method, new technologies or new system, these must be adjusted to the farmer's situation, step by step. They should be merged with the farmer's condition as much as they can.

9.4.3 Based on Agricultural Research Support

Extension is the work that introduces the new technologies or new system of crop production. So, research in agriculture must be the source of technologies that can make change to increase crop production. Research is also one of the most essential and important component for agricultural development.

9.4.4 People Participation

Extension is the learning and practicing process. It needs the cooperation among the people involved. Farmers have to be a part of the process; so do the extension workers and others. So, extension will be more effective if the people involved with full participation.

9.4.5 Democratic Process

Extension will be more effective if the farmers are willing to join the program and make their own judgment and decision.

9.4.6 Based on Farmer's Interests and Needs

Extension work will be successful if it is based on the problem and needs of the farmers. Farmers have their own interests and needs. Extension should response to these interests and needs.

9.4.7 Set Planning and Project

Extension work is the process that takes many elements and time. Then, planning and project set up according to the purpose and target for the successful are necessary. Extension needs to be planned for the better operation, monitoring and evaluation.

9.4.8 Use of Local Academic Resources

Local wisdom, local knowledge and indigenous knowledge are a must that extension worker has to take into account. Because local wisdom or academic resources will make new technologies appropriate to what farmers have. Farmers will be happier when their local wisdom has been accepted and used.

9.4.9 Develop and Use Local Leaders

Local leaders are one of the most important components for extension work. They will be the channel that extension process has to carry out. Farmer leaders can assist the extension work and they should be developed for more efficient operation. Thailand has used the system of selection of the leaders. The one who is capable will work closely with extension workers and farmers. Contract farmer (COF) is the leader in development programs that exit in Thailand.

9.4.10 Work With, Not Work For

Success of agricultural extension is to make the farmers learn how to practice by themselves. Ultimate goal of extension is that the farmers are self-reliance. They have to be on their own. Extension work provides only advice and suggestion for their own consideration and decision.

9.4.11 Based on Bottom Up Process

Extension should start from what farmers have and what they are; so problem and needs should start from farmers up to the policy and implementation level for the better service. Extension work should depend on the farmer's situation and adoption as the policy of the top.

9.4.12 Use Subject Matter Specialist (SMS)

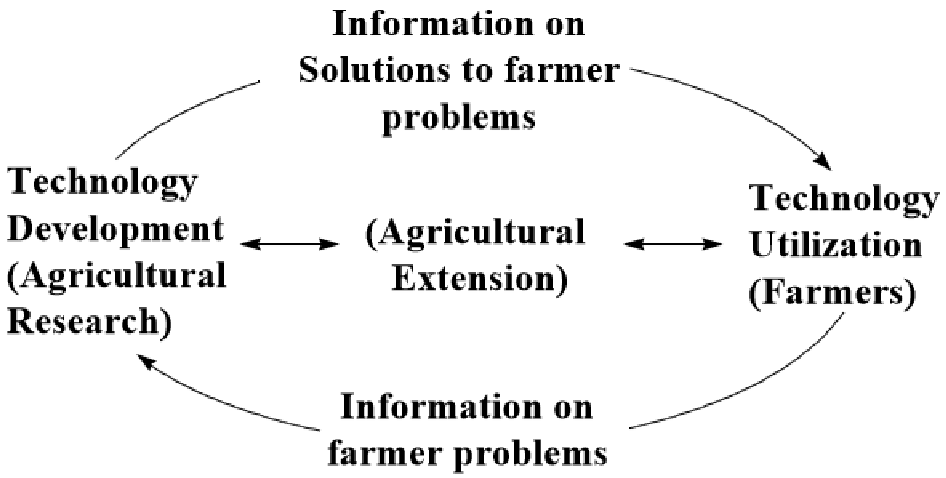
Extension needs specialty in specific problem and specific technologies. SMS can solve the problem of the farm at the right spot; thus technology has to come from specialist.

9.4.13 National Policy

Extension work is the process that makes farmer produce better production and better income. But national policy is one of the most important elements which the farmers have to follow to get full support. Therefore, extension workers have to inform the farmers about the national policy and give a strong support to the farmer. In this way, the farmers will be more successful.

9.5 Agricultural Extension Approach and Methodology

Agricultural extension process is the vehicle that transfers the information to the farmers. Technologies have to be developed and be available to the farmer for production development. How can farmers receive these technologies? There are many forms that extension work can approach the farmers for transferring the knowledge through different methods and strategies. Fig. 4 shows the concept of technology development, transfer of information, and utilization (Swanson 1984).



Source: Swanson, E.B. 1984 Agricultural Extension Reference Manual P.89

Fig. 4. Simple concept of technology development Agricultural extension approach has been developed in many forms. Normally there will be nine common forms of approach (Swanson 1984). They are:

9.5.1 Conventional Agricultural Extension Approved

This approach has clarified as the ordinary work in the third-world countries where they work on a day-to-day basis, and it must go along with the national system. The objective is to increase national agricultural production, farm income, and quality of life of the rural population. Organization for this extension is mostly from the central government under the Ministry of Agriculture.

9.5.2 Training and Visit (T&V) System

This system is the development system of approach to improve the effectiveness which is encouraged and supported by the World Bank to be used in the third-world countries. Objectives are the same as conventional approach by increasing agricultural production at the individual farm level. The objectives of the T&V system as a reform movement of conventional agricultural extension organizations should also be described. Some of the more important problems the T&V system attempts to be solved are:

(a) to improve the organization of extension by introducing a single, direct line of technical support and administrative control, (b) to change the multi-purpose role of many extension workers to a clearly defined, single-purpose role involving only education and communication activities, (c) to improve coverage by limiting the number of farm families or households one extension worker is expected to visit, (d) to improve mobility by providing appropriate transport so each worker can regularly visit his or her contact farmers, (e) to improve each extension worker's technical skills and knowledge about improved agricultural technology be providing regular in-service training sessions, (f) to improve extension's ties with agricultural research through the addition of more subject-matter specialists, who are expected to maintain regular contact with their research counterparts and to ensure a continuing flow of information that transmits technology to farmers and farmer problems back to research personnel, (g) to improve the status of extension personnel by giving them a relatively clear-cut extension job with reasonable expectations that they can successfully carry it out; this will increase their level of respect in the community and begin to build their self-confidence, and

(h) to reduce the duplication of services that occurs when extension is fragmented among different ministries (for example, agriculture, livestock or forestry) or is added to new area or commodity development schemes in a country or province that already has a general agricultural extension system. Organization and scope of T&V system is based on the total number of farm families or household. In the case of Thailand, the ratio of responsibility of each extension worker to farmers is 1 : 800 or 1 : 1,000.

9.5.3 Agricultural Extension Organized by Universities

This approach was founded in the United States. The program is carried out by federal, state and local government as well as by land-grant colleges and universities in each state, the so-called Cooperation Extension. The university will be responsible for the work with the staff from the colleges and extension centers through the experiment stations located around the state. In addition to the above three forms of extension approaches, there are also other approaches that should be employed as an alternative approach as well (Axinn 1988). They are:

9.5.4 The Commodity Specialized Approach

The assumption here is that the way to increase productivity and production of a particular commodity is to group all functions relating to it under one administration, including extension along with research, input supply, output marketing, and often prices. Extension program planing is controlled by a commodity organization, and implementation is through field staff of the organization. Resources tend to be provided by the commodity organization, for which agricultural extension is considered a sound investment. While it may use many of the same methods and techniques as the approach mentioned above, the measure of success is usually the total production of the particular crop.

9.5.5 The Agricultural Extension Participatory Approach

Here the assumption is that farming people have much wisdom regarding production of food from their land, but their levels of living could be improved by learning more of what is known outside. It further assumes that effective extension cannot be achieved without the active participation of the farmers themselves as well as of research and related service; that there is a reinforcing effect in group learning and group action; and that extension efficiency is gained by focusing on important points based on expressed needs of farmers and by reaching more small farmers through their groups/organizations instead of through individualized approaches.

The purpose is to increase production and consumption and enhance the quality of life of the rural people. Program planning is controlled locally. If such groups as farmers' associations do not exist, the extension staff should assist to form them.

Priorities vary greatly from place to place and from time to time within the country. Field personnel tend to be local, lower cost, with training and background appropriate to local needs. Resources required tend to be less than with other approaches, and a high proportion may be provided locally. Implementation is through group meetings, demonstration, individual and group level, and also local sharing of appropriate technologies. Success is measured through the number of farmers actively participating and benefiting as well as continuity of local extension organization.

9.5.6 The Project Approach

This approach assumes that rapid agricultural and rural development is necessary and that the large government bureaucracy in the regular Ministry of Agriculture. Extension service is not likely to have a significant impact upon either agricultural production or rural people within an appropriate time frame, and that better results can be achieved by taking a project approach in a particular location, during a specified time period, with large infusions of outside resources.

The purpose is often to demonstrate what can be done in a few years. Central government controls program planning, often with considerable input from international development agency. Implementation typically includes project allowances for field staff, housing rather than regular governments programs, and foreign advisors for local staff. Short-run change is the measure of success.

9.5.7 The Farming Systems Development Approach

The assumption with this approach is that technology which fits the needs of farmers, particularly small farmers, is not available, and needs to be generated locally. The purpose is to provide extension personnel (and through them farm people), with research results tailored to meet the needs and interests of local farming system conditions.

Program plans evolve slowly during the process, and may be different for each agro-climatic farm eco-system type since they include a holistic approach to the plants, the animals, and the people in a particular location.

Field personnel tend to be highly specialized, relatively expensive, and from outside the area being served. Implementation is through a partnership of research and extension personnel with each other and with local farmer, taking a “systems approach” to the farm, and sometimes involving several different scientific farmers’ fields and homes. The measure of success is the extent to which farm people adopt the technologies development by program and continue to use them over time.

9.5.8 The Cost-Sharing Approach

The assumption here is that the program is more likely to fit local situations and personnel are more likely to serve local people’s interests if part of the cost of agricultural extension is paid locally. It also assumes that farm people are too poor to pay the whole cost, so central and regional governments typically provide most of it.

Helping farm people learn those things they need to know for self-improvement and increased productivity is the purpose. Control of program planning is shared by the various levels paying the costs, but must be responsive to local interests in order to maintain ‘cooperative’ financial arrangements. Field personnel tend to be recruited locally, cost less, and remain in one location for long periods of time. Because of the nature of this approach, resources required from central governments tend to be less. Success is measured by farm people’s willingness and ability to provide some share of the cost, individually or through their local government units.

9.5.9 The Educational Institution Approach

In this approach, the assumption is that faculties or colleges of agriculture have technical knowledge which is relevant and useful to farm people. The purpose is to help those people learn about scientific agriculture. Program planning tends to be controlled by those who determine the curriculum of the education institution. Implementation is through non-formal instruction in groups, with individuals, and with other methods and techniques, sometimes conducted by a college or university with agricultural extension personnel of another agency as the main audience. While considerable resources are required, since they are shared between the classroom program of the educational institution and agricultural extension, the approach can be attendance and the extent of participation by farm people in the school's agricultural extension activities.

9.6 Methods of Extension

Farmers will learn to use the technologies for their cultivation practices and develop the production. How they learn and how to teach and train seem to be concerned to extension worker. The success of the transfer of knowledge to the farmers are the methods and techniques that make the farmers learn efficiently and effectively. There are depended on how the extension worker will consider using the appropriate methods for the teaching. Some conditions to take into account.

- For farmers, or receivers, or learners who will be the part of the end transferring of the knowledge, there have to have some conditions concerned with farmers such as age, character, culture, education, tradition, and environment. Farmers in some part of the world are easy to learn but in some part, they are not. They are different from one society to another. The extension workers have to consider this factor as well.

- Extension workers, or trainers, or teachers, who will be responsible to transfer the knowledge to the farmers, have to understand the farmers and how to transfer the knowledge. They have to have knowledge of transferring and know how to work and train the farmers. Also, they have to have the techniques and experience to deal with the farmers and know the role as the trainer.

- Technology or knowledge that will be transferred to the farmers have to be considered on what to transfer. Extension workers have to consider appropriate knowledge to the farmers which should not be lower or higher level to the farmers. Knowledge has to be based on the need and usefulness to the farmers and must be appropriate for adapt to the local wisdom or indigenous knowledge of the farmers as well.

- Environmental conditions include time and place to be transferred, and the knowledge which depends on the farmer situation, should be under the circumstance that suits the farmers and extension workers.

The above four factors will make more effective transfer of knowledge to the farmers with the appropriate methods. Extension methods which mostly followed what FAO has recommended are:

- **Individual Method:** This method will transfer the knowledge to the farmers one by one, or face to face. There are many techniques that are used, including farmers and home visit, office calls, letters, telephone calls, and informal discussion. This method is effective as each farmer will learn directly of specific knowledge from the extension workers. Mostly farmers have low education level and it takes more time to teach them.

- **Group Method:** This method involves the extension worker transfer the knowledge to the group of the farmers who will learn from each other as well. These include group meetings, demonstrations of both method and result, field study tour or field trip, and field day. This group method will be more effective if the farmers are homogeneous group, i.e having the same culture, level of education, and language. Farmers must have middle to high level of education, and less time to teach than the individual method.

- **Mass Method:** This method is the way that knowledge will be transferred to the mass media which include radio broadcasting, television, newspaper, poster and exhibition. This method will be the process that transfers knowledge to the large number of farmers who can learn by them- selves. So, the farmers have to have the high level of education, and will be effective in terms of less time, but disadvantage in terms of the knowledge received.

9.7 Vetiver Extension and Promotion

From the agricultural extension and training (education) programs, these are the processes on how to make the farmers or clienteles' to accept and adopt the technology for production development. Agricultural extension process is an important process that all concerned people have to be aware of because the adoption process is the result of the efficient transfer process.

Many times, farmers drop the technology and do not adopt it; that makes the extension program fail. Technologies and transfer process must be considered seriously, because technologies that will be transferred have to give the benefit and the development or the change to the farmers.

9.8 The Dissemination of the Vetiver System

Vetiver system is the technology that is useful to the farmers in terms of:

- Soil fertility and water conservation
- Soil protection
- Soil capability development
- Support the moisture to crops.

So, vetiver has the utility that is not direct to agricultural production, unlike other crops grown by the farmers who still want to grow them, and ignore to take an interest on vetiver. That makes its extension and promotion the most difficult. But, it is a challenge for the extension workers to make it work through promotion campaign. Extension and promotion of vetiver must be done through the system that includes:

- Knowledge about Vetiver System Technology.

- Long-term benefit to the farmers.
- Ultimate goal of the vetiver growing has to be clarified.
- Benefit of by-products has also to be clearly identified.

Thus extension workers and researchers have to prepare vetiver extension program carefully in order for the farmers to have more understanding and will accept and adopt this technology.

10.0 STATUS OF VETIVER SYSTEM TECHNOLOGY

Based on the feedback by the vetiver users around the world, the responses are adapted as below (Grimshaw 2008):

- ✓ **Lack of knowledge and technology dissemination:** This covers a wide range including ignorance of the technology by administrators, policy makers and planners, uninformed technical professionals and lack of profession endorsement, teaching and learning limitations in universities and schools, limited press coverage, absence of mass marketing, lack of publications, language barriers, and not using modern marketing tools.

- ✓ **Leadership:** New technology introduction requires farsighted leadership with vision and commitment. A committed lead organization is required. Good NGOs and private sector companies can often do this best. Commitment is rarely found in government organizations.

- ✓ **Low-cost solution and problems thereof:** Not always, but generally VS is seen as a low-cost technology that does not attract high budget allocations, and therefore the opportunities and attractiveness for corrupt practices are much less than for high-cost alternatives.

- ✓ **Technology:** Majority of solutions have in the past an engineering base. Most engineers have not been trained in bioengineering solutions, particularly those that are low cost. Low-cost biological solutions are often seen as too simple and as such are unattractive. Again applying low-cost solutions results in lower fees for designers and executing contractors. Many higher-cost engineering solutions do not always last long and have to be replaced.

- ✓ **Specifications:** Specifications and standards should be followed; bad application generally results in failure and detracts potential users. Site specification is important. Often rather general standards are given and followed, and if not properly supervised and fine-tuned, it can lead to failure.

- ✓ **Multipurpose Use:** For some potential user groups such as railway and highway engineers, it is best to have narrowly focused workshops and training on the application at hand. For other users such as farmers and rural planners, there is a need to look at the wider aspects and the multi-benefits that are possible from VS.

- ✓ **Plant Propagation:** Because vetiver has to be vegetatively propagated, an upfront investment and lead time are required. This can be detraction. However, there are plenty of demonstrations showing that small farmer private nurseries can be quickly established if there is a guaranteed market.

- ✓ **Invasive species and native plant syndrome:** This is more of a problem in developed countries. Sometimes deliberate miscasting of vetiver as an invasive species. Many government projects in the United States will only use native plants. Also entrenched vested interests in other more "profitable" technology work hard to keep VS out, and the "invasive" slur is a handy tool to frighten unaware decision-makers.

- ✓ **Research:** Some research has been very adequate, but more has to be done for field application.

- ✓ **Maintenance Requirements:** Once vetiver is well established on the selected site, usually within one growing season, it generally becomes self-repairing by regeneration and growth and requires little maintenance. However, a newly installed project will require careful periodic inspections until it is established. Established vegetation is vulnerable to trampling, drought, grazing, nutrient deficiencies, toxins, and pests and may require special management measures at times.

- ✓ **Limitation:** Vetiver System (VS) measures should not be viewed as a panacea or solution for all slope failure and surface erosion problems. VS have unique attributes, but are not appropriate for all sites and situations. In certain cases, a conventional vegetative treatment (e.g., grass seeding and hydro-mulching) works satisfactorily at less cost. In other cases, the more appropriate and most effective solution is a structural retaining system alone or in combination with soil bioengineering.

- ✓ **Vetiver Growth:** Vetiver plantation is suitable for protecting slopes in different geographic areas with different soils and climatic conditions. However, the growth of vetiver roots and shoot varies in different areas. These are due to the differences in soil type, nutrient content, salinity, and climatic conditions. Even in high saline zone area, vetiver plantation is a suitable solution to protect the side slopes of shrimp ponds from flood and wave actions.

- ✓ **Livelihood Propagation:** Vetiver grass is traditionally used by communities for livelihoods; however facilitation of Vetiver products across the country needs motivation and cooperation from government.

References for Sections 3.1-3.7

Adams, R.P. 2000. DNA analysis of genetic diversity of Vetiver and future selections for use in erosion control. *In:* Proceedings of ICV-2, 18-22 Jan. 2000, Phetchaburi, Thailand, pp. 31-47.

BOSTID. 1993. Vetiver Grass - A Thin Green Line against Erosion. National Research Council, National Academy Press. Washington, DC.

Dalton, P.A.; Smith, R.J.; and Truong, P.N.V. 1996. Hydraulic Characteristics of Vetiver Hedges: An Engineering Design Approach to Flood Mitigation on a Cropped Flood Plain. 11 pp. (unpublished).

Greenfield, J .C. 1988. Moisture conservation: Fundamental to rain fed agriculture. ILEIA. 4: 15-1 7.

Greenfield, J.C. 1995. Vetiver Grass (*Vetiveria* spp.) - The Ideal Plant for Vegetative Soil and Moisture Conservation. *In:* Vetiver Grass for Soil and Water Conservation, Land Rehabilitation, and Embankment Stabilization.

Richard G. Grimshaw and Larisa Helfer, eds. World Bank Technical Paper No. 273, pp. 3-38.

Grimshaw, R.G. 1990. Vetiver Newsletter. Newsletter of the Vetiver Information Network, ASTAG, World Bank, No.3.

Grimshaw, R.G. 1991. Vetiver Newsletter. Newsletter of the Vetiver Information Network, ASTAG, World Bank, No. 7.

Namwongprom, K; Nanakorn, W.; Paopun, Y.; and Norsaengsri, M. 2000. Revision of the genus *Vetiveria* Bory in Thailand. *In:* Abstracts of Poster Papers presented at ICV-2, 1822 Jan. 2000, Phetchaburi, Thailand, p. 23.

Nanakorn, W.; and Chinapan, W. 2000. Vetiver Ecotypes. *In:* Manual on Factual Tips About Vetiver Grass. ORDPB, Bangkok, pp. 13-31.

Nanakorn, W.; Chinapan, W. and Tepnaraprapai, P. 2000. What is Vetiver Grass? *In:* Manual on Factual Tips About Vetiver Grass. ORDPB, Bangkok, pp. 1-12.

ORDPB. 1995. Vetiver Grass for Environment Protection and Other Usages. *In:* Thailand‘s Experiences-II. ORDPB, Bangkok.

References for Sections 4.1-4.5

Adams, R.P. 2000. DNA analysis of genetic diversity of vetiver and future selections for use in erosion control. *In:* Preceedings ICV-2, 18-22 Jan. 2000, Phetchaburi, Thailand, pp. 31-47.

National Research Council. 1993. Vetiver Grass: A Thin Green Line Against Erosion. National Academy Press. Washington, D.C.

Dalton, P.A.; Smith, R.J.; and Truong, P.N.V. 1996. Hydraulic Characteristics of Vetiver Hedges: An Engineering Design Approach to Flood Mitigation on a Cropped Flood Plain. Unpublished manuscript.

Greenfield, J.C. 1988. Moisture conservation: Fundamental to rain fed agriculture. ILEIA 4 (4): 15-17.

Greenfield, J.C. 1995. Vetiver Grass (*Vetiveria* spp.) - The Ideal Plant for Vegetative Soil and Moisture Conservation. *In:* R.G. Grimshaw and L. Helfer, eds. Vetiver Grass for Soil and Water Conservation, Land Rehabilitation, and Embankment Stabilization. World Bank Technical Paper, No. 273, pp. 3-38.

Grimshaw, R.G. 1990. Vetiver Newsletter. Newsletter of the Vetiver Information Network, ASTAG, World Bank, No. 3, March 1990.

Grimshaw, R.G. 1991. Vetiver Newsletter. Newsletter of the Vetiver Information Network, ASTAG, World Bank, No. 7, November 1991.
Namwongprom, K.; Na Nnakorn, W.; Paopun, Y.; and Norsaengsri, M. 2000. An overview of genus *Vetiveria* Bory in Thailand. Paper presented at ICV-2, 18-22 Jan. 2000, Phetchaburi, Thailand (unpublished).
Nanakorn, W.; and Chinapan, W. 2000. Vetiver Ecotypes. *In:* Factual Tips About Vetiver Grass. ORDPB, Bangkok, pp. 13-31.
Nanakorn, W.; Chinapan, W.; and Tepnaraprapai, P. 2000. What is Vetiver Grass? *In:* Factual Tips About Vetiver Grass. ORDPB, Bangkok, pp. 2-12
ORDPB. 1995. Vetiver Grass for Environment Protection and Other Usages: Thailand's Experiences. ORDPB, Bangkok.
Smith, R. 1996. Notes on the Hydraulics and Sediment Trapping of Vetiver Hedges on Steep Slopes. Nat. Center for Eng. in Agric., Univ. Southern Queenland. (unpublished).
Sunanthapongsuk, V. 2000. Study on soil microbial biodiversity in rhizosphere of vetiver grass in degrading soil. *In:* Abstracts of Poster Papers presented at ICV-2, 18-22 Jan. 2000, Phetchaburi, Thailand.

References for Section 5

Anusonpornperm, S.; Supattanakul, W.; Pongpangan, L.; Wattanakul, J.; and Wilairat, P. 2000. The use of dibbling tube in vetiver propagation. In: Abstracts of poster papers presented at ICV-2, p. 35, ORDPB, Bangkok.
Bernal, H.Q. 2000. Effe cts of two growth r egulators on development of vetiver cuttings. In: Abstracts of poster papers presented at ICV-2, p. 37, ORDPB, Bangkok.
Chalothorn, C.1998. Planting vetiver using the bare root soaking technique. In: Proc. ICV-1, p. 44, ORDPB, Bangkok.
Charanasri, U.; Sumanochitrapan, S.; and Topangteam, S. 1996. Vetiver grass: Nursery development, field planting techniques, and hedge management. An unpublished paper presented at ICV-1, Chiang Rai, Thailand, 4-8 Feb.96.
Chomchalow, N. 2000. Techniques of vetiver propagation in Thailand. AU J.T. 3: 113-124.
Ho, H.T.; Manarang, M.N.S.J.; and Anicete, A.B. 2000. Increased efficiency in vetiver propagation with the use of growth promoters. In: Proc. ICV-2, ORDPB, Bangkok (in press).
Inthapan, P.; and Boonchee, S. 2000. Research on Vetiver Grass for Soil and Water Conservation in the Upper North of Thailand. In: Proc. ICV-2, ORDPB, Bangkok (in press).
Khao Hin Son Royal Development Center. 1998. Development and Promotion for the Utilization of Vetiver Grass. Khao Hin Son Royal Development Study Center, Chacheongsao, Thailand (in Thai).
Namwongprom. K; and Nanakorn, M. 1992. Clonal propagation of vetiver in vitro. In: Proc. 30th Ann. Conf. on Agriculture, 29 Jan-1 Feb 92 (in Thai).
Nanakorn, M.; Surawattananon, S.; Wongwattana, C.; Namwongseprom, K.; and Suwannachitr, S. 1996. In vitro induction of salt tolerance in vetiver grass. In: Abstracts of papers presented at ICV-1, p.33, ORDPB, Bangkok.
National Research Council. 1993. Vetiver Grass: A Thin Line Against Erosion. National Academy Press, Washington, D.C.
Sukkasem, A.; and Chinapan, W. 1996. Tissue culture of vetiver grass. In: Abstracts of Papers presented at ICV-1, p. 61, ORDPB, Bangkok.

Thiramongkol, V.; and Baebprasert, B. 2000. The Vetiver Grass Pot: Production and Utilization. In: Proc. ICV-2, ORDPB, Bangkok (in press).
Yoon, P.K. 1991. Extracts from A Look-See at Vetiver Grass in Malaysia - First Progress Report. Vetiver Newsl. 6: 86-96.

References for Section 6.1

Calegari, A. 2000. No-tillage system in south Brazil. In: Response to Land Degradation, eds. E.M. Bridges, I. Hannam, R.L. Oldeman, F.W.T. Penning de Vries, S.J. Scherr and S. Sombatpanit. Science Publishers, Enfield, NH.
Enters, T. 1997. Adoption: Section review. In: Soil Conservation Extension: From Concepts to Adoption, eds. S. Sombatpanit, M.A. Zoebisch, D.W. Sanders and M.G. Cook. pp. 399-403. Science Publishers, Enfield, NH.
Erenstein, O. 1999. The Economics of Soil Conservation in Developing Countries: The Case of Crop Residue Mulching. Doctoral Thesis, Wageningen Agric. Univ. Wageningen,Netherlands .
Fujisaka, S. 1991. Thirteen reasons why farmers do not adopt innovation intended to improve the sustainability of upland agriculture. In: Evaluation for Sustainable Land Management in the Developing World, eds. J. Dumanski, E. Pushparajah, M. Latham and R. Myers. pp. 509-522. IBSRAM, Bangkok.
Giger, M.; Liniger, H.; and Critchley, W. 1999. Use of direct incentives and profitability of soil and water conservation in Eastern and Southern Africa. In: Incentives in Soil Conservation: From Theory to Practice, eds. D.W. Sanders, P.C. Huszar, S. Sombatpanit and T. Enters. pp. 247-274. Science Publishers, Enfield, NH.
Hudson, N.W. 1982. Soil Conservation. 324 pp. Batsford, London.
Hudson, N.W. 1991. A Study of the Reasons for Success or Failure of Soil Conservation Projects. FAO Soils Bulletin 64. 65 pp. FAO, Rome.
McDonald, M.; and Brown, K. 1999. Issues and Options in the Design of Soil and Water Conservation Projects. School of Agricultural and Forest Sciences. Publ. No. 17. Univ. of Wales, Bangor, UK.
Palmer, J.J.; Guliban, E.; and H. Tacio. 1999. Use and success of incentives for promoting Sloping Agricultural Land Technology (SALT) in the Philippines. In: Incentives in Soil Conservation: From Theory to Practice, eds. D.W. Sanders, P.C. Huszar, S. Sombatpanit and T. Enters. pp. 309-324. Science Publishers, Enfield, NH.
Rogers, E.M. 1962. Diffusion of Innovation. Free Press of Glencoe, New York.
Reij, C. 1998. How to increase the adoption of improved management practices by farmers? In: Towards Sustainable Land Use, eds. H.-P. Blume, H. Eger, E. Fleischhauer, A. Hebel, C. Reij and K.G. Steiner. Vol. 1. pp. 1413-20. Catena Verlag, Reiskirchen, Germany.
Sombatpanit, S.; and Renaud, F.G. 1997. Strategies: Section review. In: Soil Conservation Extension: From Concepts to Adoption, eds. S. Sombatpanit, M.A. Zoebisch, D.W. Sanders and M.G. Cook. pp. 99-105. Science Publishers, Enfield, NH.Sombatpanit, S.; Sangsingkeo, S.; Palasuwan, N.; and Saengvichien, S. 1993. Soil conservation and farmers acceptance in Thailand. In: Acceptance of Soil and Water Willcocks, T.J.; and Critchley, W. 1996. Ancient and modern: Towards a new methodology for evaluating and improving historical traditions of soil and water conservation. In: Proc.Workshop on the Evaluation of Indigenous Soil and Water Conservation, Nyeri, Kenya, May 1998. eds.

References for Sections 6.2 - 6.5

Chen, S. 1999. Insect on vetiver hedges. AU J.T. 3: 38-48; and www.vetiver.org.

Hengchaovanich, D. 2000. VGT: A bioengineering and phytoremediation option for the new millennium. *In:* Preceedings of ICV-2, 18-22 Jan. 2000, Phetchaburi, Thailand, pp. 25-30.

Inthapan, P.; Anecksamphant, C.; and Boonchee, S. 1996. Comparison of effectiveness of Differences vertical intervals, row number and plant spacing of vetiver grass for soil and water conservation. Proc. ICV-2, pp.

Inthapan, P.; and Boonchee, S. 2000. Research on vetiver grass for soil and water conservation in the upper north of Thailand. *In:* Preceeding of ICV-2, 18-22 Jan. 2000, Phetchaburi, Thailand, pp. 368-379.

Kanchanadul, V.; Udpuang, N.; Inthapan, P.; and Boonchee, S. 1998. Comparison of soil and moisture content by using different cropping patterns for soil and water conservation on steep land. Paper presented at the 5th Department of Land Development Research Workshop, 1998. Kanchanaburi, Thailand (in Thai).

Land Development, Department of. 1998. Report of Development Seminar, 20-30 Jan. 1998. Sara Buri, Thailand (in Thai).

Land Development, Department of. 1999. Annual Report. Department of Land Development, Bangkok, Thailand.

Meyer, L.D.; Dabney, S.M.; and Harmon, W.C. 1995. Sediment trapping effectiveness of stiff grass hedges. Trans ASAW 38: 809-15.

Peukrai, S.; Inthapan, P.; and Boonchee, S. 1994. The effect of land and crop management on soil erosion on the highland of northern Thailand. Poster presented at 2nd Department of Land Development Research Workshop, 8-11 May 1994, Phetchaburi, Thailand (in Thai).

Techapinyawat, S.; Sripen, K.; Komkriss. T. 1996. Allelopathic effiicts of vetiver grass on weeds. Proc. ICV-1, pp. - .

Truong, P.N.V.; Datlon, P.A.; Knowles-Jackson, C.; and Evans, D.S. 1996. Vegetative barrier with vetiver grass: An alternative to conventional soil and water conservation systems. Proc. 8th Australian Agronomy Conf. Toowoomba, Australia, pp. 550-3.

Truong, P.N. 1999. Vetiver grass technology for land stabilization, erosion and sediment control in the Asia Pacific region. Paper presented at First Asia Pacific Conf. Ground and Water Bio-engineering for Erosion Control and Slope Stabilization. Manila, Philippines, April 1999.

Truong, P.N.; and Baker, D. 1998. Vetiver Grass System for Environmental Protection. Technical Bulletin No. 1998/1. PRVN / ORDPB, Bangkok.

Troung, P.N. 2000. The global impact of vetiver grass technology on the environment. *In:* Preceedings of ICV-2, 18-22 Jan. 2000, Phetchaburi, Thailand, pp. 48-61.

References for Section 7.1

Bracken, N.; and Truong, P. 2000. Application of vetiver grass technology in the stabilization of road infrastructure in the wet tropical region of Australia. In: Preceedings ICV-2, 18-22 Jan. 2000, Phetchaburi, Thailand. pp 467-72. Gray, D.H. 1994. Influence of vegetation on the stability of slopes. In: D H Barker, ed. Vegetation and slopes. Thomas Telford, London. Gray, D.H.; and Leiser, A.T. 1982. Biotechnical Slope Protection and Erosion Control. Van Nostrand Rheinhold, New York.

Hengchaovanich, D. 1998. Vetiver Grass for Slope Stabilization and Erosion Control (with Particular Reference to Engineering Applications). Tech. Bull. No.1998/2, PRVN / ORDPB, Bangkok.

Hengchaovanich, D. 1999. 15 Years of Bioengineering in the Wet Tropics: From A (Acacia auriculiformis to V (Vetiveria zizanioides). Paper presented at First Asia-Pacific Conf. Ground and Water Bioengineering for Erosion Control and Slope Stabilization, Manila, Philippines.

Hengchaovanich, D. 2000. VGT: A bioengineering and phytoremediation option for the new millenium. In: Preceedings of ICV-2, 18-22 Jan. 2000, Phetchaburi, Thailand, pp 25-30.

Hengchaovanich, D.; and Nilaweera, N.S. 1998. An assessment of strength properties of vetiver grass roots in relation to slope stabilization. Proc. ICV-, pp 153-8. IBRD. 1995. Vetiver grass for soil and water conservation, land rehabilitation, and embankment Stabilization.

Narayanan, A.; and Hengchaovanich, D. 1986. Slope stabilization and protection for roads in mountainous terrain with high rainfall. Proc. 5th REAAA/13th ARRB Combined Conf., Adelaide, Australia, 13(3): 152-61. National Research Council. 1993. Vetiver Grass: A Thin Green Line Against Erosion. National Academy Press, Washington, D.C.

Rodiguez, O.D. 1993. Hedgerows and mulch as soil conservation measures evaluated under field simulated rainfall. Proc. Int. Workshop on Soil Erosion Process on Steep Lands, Merida, Venezuela, 16-20 May 1993.

Smyle, J. 2000. Disaster mitigation and vulnerbility reduction: An outsider's view (A natural resources perspective on the prospects of the VGT). In: preceding's of ICV-2, 18-22 Jan. 2000, Phetchaburi, Thailand. Pp.177-90.

Wright, S.F.; and Upadhayaya, A. 1998. A survey of soils for aggregate stability and glomalin, a glyco-protein produced by hyphae of arbuscular mycorrhiza fungi. Plant and Soil 198: 97-107.

Wu, T.H. 1995. Slope stabilization. In: P.C. Morgan, and R.J. Rickson, eds. Slope Stabilization and Erosion Control: A Bioengineering Approach.

Xu, L. 1999. An overview of the use of vegetation in China. Paper presented at the Int. Conf. Vetiver Bioengineering Technology for Erosion and Sediment Control and Civil Construction Stabilization, Nanchang, China.

References for Section 7.3

Muensangk, S. 2000. The use of vetiver grass for reclamation and improvement of acid sulfate soils in Thailand. I. Pre-experimental study. In: preceding's ICV-2, 18-22 Jan. 2000, Phetchaburi, Thailanad, pp. 288-293.

References for Section 7.4

Chanyotha, S. 2000. Phytoremediation by vetiver grass: Field and laboratory investigation. In: Abstracts of paper presented at ICV-2, 18-22 Jan. 2000, Phetchaburi, Thailand. p. 15. Liao, X. 1999. Personal communications.
Pinthong, J.; Impithuksa, S.; Udomchoke, M.; and Ramlee, A. 1998. The capability of vetiver hedgerows on decontamination of chemical residues. Proc. ICV-1, 4-8 Feb. 1999, Chiang Rai, Thailand. pp. 91-98.
Sripen, S.; Komkris, T.; Techapinyawat, S.; Chantawat, S.; Masuthon, M.; and Rungsuk, M. 1996. Growth potential of vetiver grass in relation to nutrients in waste water of Changwat Petchburi. In: Abstract of paper presented at 1st. Int. Conf. on Vetiver, 4-8 Feb. 1996, Chiang Rai, Thailand. p. 44.
Truong, P. 2000. The global impact of vetiver grass technology on the environment. In: Preceedings of ICV-2, 18-22 Jan. 2000, Phetchaburi, Thailand. pp. 48-61.

References for Section 7.5

Charanasri, U. 2000. Vetiver and Natural Disaster: Doi Tung Experience: Proc. ICV-2 (in press).
Cheng, H.; Wang, F.; Li, Y.; and Hu, G. 2000. Experiment of the Application of Vetiver to Sand-Fixing in Subtropical Deserts. In: Preceding of ICV-2, pp. 171-6.
Hengchaovanich, D. 2000. Report of the RDPB Mission in Madagascar. Vetiverim 14: 8-9
Shelton, R. 2000. Vetiver and Natural Disasters: Prevention and Rehabilitation. In: Proceedings' of ICV-2, pp. 165-70.
Smyles, J. 2000. Disaster Mitigation and Vulnerability Reduction: An Outsider's View (A Natural Resources Perspective an the Prospects of the VGT). In: Proceedings of ICV-2, pp. 177-90.

References for Section 9.0

Angkasith, P. 1995. Supervision in Agricultural Extension. P.R. Computer Printing Shop, Chiang Mai, Thailand (in Thai).
Adkikaya, R. 1994. Strategic Extension Campaign, A Participatory-Oriented Method of Agricultural Extension. FAO, Rome.
Axinn, H.G. 1988. Guide on Alternative Extension Approaches. FAO, Rome. Roger, E.M. 1983. Diffusion of Innovations. 3rd ed. Free Press, New York. Swanson E.B. 1984. Agricultural Extension: A Reference Manual. FAO, Rome.
Wiboonpongse, A. 1996. Analysis of Factors Influencing Farmer's Adoption of Technology. Paper presented at IBSRAM Training Program. Chiang Mai, Thailand.