Final Report for Vetiver Planting Training and Implementation in Tuvalu

Mr. Robinson Vanoh

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1 Summary for Policy Makers

1.1 Background Information

In a recent survey, the Tuvalu Ridge to Reef survey team identified the main sources and causes of pollution in the lagoonal coasts which has resulted in increase in algal bloom, especially by the *Sargassum polycystum,* which is an invasive species in Tuvalu. First sightings of these species by the Tuvaluans at the lagoon in Funafuti was between 2010 and 2011. Recordings in the distribution, biomass and abundance of *S. polycystum* was done during key studies done by the University of the South Pacific in 2013 and by the French Research Institute for Sustainable Development (IRD) in 2015. Another important study that was published in 2013 by Japanese scientists showed chronic pollution levels in the Funafuti lagoon. The main source of pollution in the lagoon as identified in these study was wastewater seepage from bottomless septic tanks from households in Funafuti.

From the present survey conducted in October 2017 by the Tuvalu Ridge to Reef team, two key causes were identified for the overgrowth of *S. polycystum* at the Funafuti Lagoon. These are: (1) Very high pollution levels into the Funafuti lagoon from Poor Waste Water Management on land; that is from (a) septic tanks that do not have sealed floors/bottoms, (b) unregulated pigsties, (c) Poor Waste Management at the Funafuti landfill and (d) discharges from arriving vessels. (2) The La Niña event of 2010 that brought low-temperature water into the Funafuti lagoon, with decreased rainfall for an extended period and the changing the wind direction leading to high concentration of pollutants in the lagoon and favourable conditions for reproduction, growth and distribution of *S. polycystum.* Hence, the first cause is manageable if we can take a holistic approach in implementing the recommendations made by the survey team in their mission report.

These growths are making the environment unfavourable for growth of good algae species, corals and other useful living marine organisms, therefore managing the Wastewater in Tuvalu is critically important. The Vetiver System Technology, a proven technology which is in use in over 100 countries in dealing with wastewater problems will help to eliminate or reduce these problems currently faced in Tuvalu. It is therefore very important for us to manage the problem, rather than the problem managing us.

1.2 Key Recommendations

To follow the Ridge to Reef Project survey team recommendations listed in 1.3 for the implementation of the Vetiver System Technology in managing of wastewater from these sources, I further propose following recommendations for possible upscaling in Funafuti and possible rollout to the outer Islands.

1.3 Water Quality and Decontamination

Landfill Site

It is recommended that the lower side of the landfill, towards the lagoon side cleared of weeds and continued with planting of the Vetiver grass, continue from the four hedgerows that were planted as a pilot during the Education Campaign Awareness (Refer Annex 1). The old landfill site that has been covered with sand, to also have vetiver planted on top as a hedgerow to control erosion, stabilize slope and to treat contaminants from leaching into the lagoon.

Improved waste collection services, Segregation of wastes at source, smashing of larger wastes such as drums, washing machine, old cars etc. before dumping into the dug pits is also important. Dug pits to have 3-4 hedgerows of vetiver planted will help reduce contaminants from leaching into the lagoon. Upscaling and application to landfill sites on the outer Atolls is also recommended.

Tafua Pond

Unregulated dumping of wastes from the pigsties is of a major concern, as evident from the growth of blue-green algae in the pond and the Water Quality Assessment results (refer table 1), indicating high volume of Nitrogen (N) and Phosphate (P) present in the pond. The pond is depleted of Dissolved Oxygen (DO) making aquatic life difficult to live.

The strategy is to prevent contaminated runoff and leachate to reach the pond by planting Vetiver grass along the edges of the pond near the pigsties, however it looks near impossible in some areas as the buildings are built right into the pond. It is therefore recommended, for the relocation of the pigsties to a centralised location. Once relocated, four (4) vetiver hedgerows to be planted along the edges of the pond to clean the soil of contaminants and the site revegetated for recreational purposes.

Normally vetiver pontoons are recommended for the pond, but present analysis indicated that the pond water is too salty for vetiver, so this application is postponed until further analysis are carried out (refer Annex 6).

Septic Tanks (Bottomless)

Waste water leaking from “bottomless” (unsealed from the bottom) septic tanks and pit toilets runs off to the lagoonal coast, carried by waves. These pollution remains a chronic problem and needs to be remediated. Wastewater runoff migrates towards the coast via underground and into the lagoon. It was recommended in the last mission report for vetiver planting, however no planting was done due to shortage of vetiver slips in the nursery and also were not ready for transplanting.

It is recommended these sites be identified, if not been identified, have them planted with four (4) rows of vetiver hedgerow around the pit. Eco-friendly toilets (refer Annex 4) are also recommended for Island communities who have no access to the main sewerage system.

Cemeteries

Planting of a Vetiver grass hedgerow around burial sites and at the edges of the cemeteries will also help to minimise contaminants from human corpse leaching into the lagoons. They can also be planted as ornamentals for landscaping within the cemetery parameters.

Coastal Erosion

The unique resilience of Vetiver grass and its ability to survive in saline soils and environments makes it especially effective applicable for coastal erosion problems in Tuvalu. Vetiver's saline threshold level is at ECse=8dsm-1, and it can survive at 18-22dSm-1 under dry land salinity conditions. It is therefore recommended that coastal sites that are highly erodible and prone to erosion be identified and Vetiver grass used to stabilize the banks. The coastal site from the Queens' Park through to the hospital (Refer Annex 5) and the Marine Protected Island (Fualopa) (Refer Annex 6) are possible sites recommended for pilot demo sites for coastal protection.

Vetiver Nurseries

The island of Vaitupu - where the Motufoua Secondary school is located - has a Department of Agriculture demonstration farm - this can be a good spot for a central nursery. Eventually nurseries must be established on all islands and be community managed.

Vetiver Training

Vetiver Education and Community Training and involvement is way forward. Each of the nine islands have a Primary School and a Community Training Centre (CTC). Simple and relevant ongoing vetiver training can be carried out in these facilities. Users must be responsible for ongoing maintenance of plantings. The R2R to set up a simple monitoring system for checking the impact. Some of the older students at the Motufoua Secondary School and Fatuvalu High School can be involved - nice practical learning project for them.

2 Introduction

Waste water management is of a major concern in Tuvalu, hence resulting in the coastal waters in the lagoons being highly polluted with contaminants, which has resulted in the algal bloom in the lagoons as reported in a recent survey by the Tuvalu Ridge to Reef survey team led by Mr. Viliamu Iese and Dr. Antoine De Ramon N'Yeurt. This research was carried out as part of the Ridge to Reef Program to identify the main causes and sources of pollution.

The overall objective of the Ridge to Reef Program in Tuvalu was "to preserve ecosystem services, sustain livelihoods and improve resilience in Tuvalu (using a 'ridge-to-reef' approach)". Is was outlined in their mission report on the outcome of the Ridge to Reef program, namely to: "increase sustainably managed landscapes and seascapes that will integrate biodiversity conservation", and implement remedial measures to reduce occurrences and severity", hence, vetiver system fits in well with these approach.

Vegetative methods, such as the Vetiver system, are the only feasible and practicable way to totally eliminate or reduce wastewater on a large scale. Tuvalu, as a developing Small Island Nation needs a sustainable and cost effective method of managing its wastewater.

As part of the remedial measures in the report, the application of Vetiver System Technology was recommended for the treatment of waste water from land sources at various sites on Funafuti as a start-up pilot project for monitoring and assessment.

Following are remedial measures implemented as pilot projects for the treatment of Wastewater from land sources.

3 Managing contaminants from the landfills leaching into the lagoons

Disposal of landfill leachate is a large problem in Tuvalu, since it is highly contaminated with heavy metals, as well as organic and inorganic pollutants. The Vetiver grass (Chrysopogon zizanioides L.) which possesses unique attributes that make it exceptional for environmental protection and rehabilitation is the suitable plant species for treating the waste water problem in Tuvalu. When applied to the landfill site, Vetiver has the ability to address a multitude of needs; (1) Leachate and Wastewater Treatment, (2) Stabilize bank along the coastline and Control erosion, (3) will protect Infrastructure, (4) will act as Silt Fence and will control flow of sediments into the lagoon.

Picture 1 & 2: Waste dumping at the Funafuti landfill site

Vetiver is best suited to leachate disposal at the landfill site due to its high water usage, nutrient absorption rates, and tolerance to elevated levels of nutrients, salt and other toxicities. When applied to the Funafuti landfill leachate, Vetiver will act to; (1) Prevent pollution of underlying and surrounding soil, (2) Prevent the pollution of ground and surface water, (3) Control the 'bioreactor' by containing and treating surface or underground egresses, (4) Stabilize the edges and walls of landfill, and (5) Control seepages from the landfill into the lagoon.

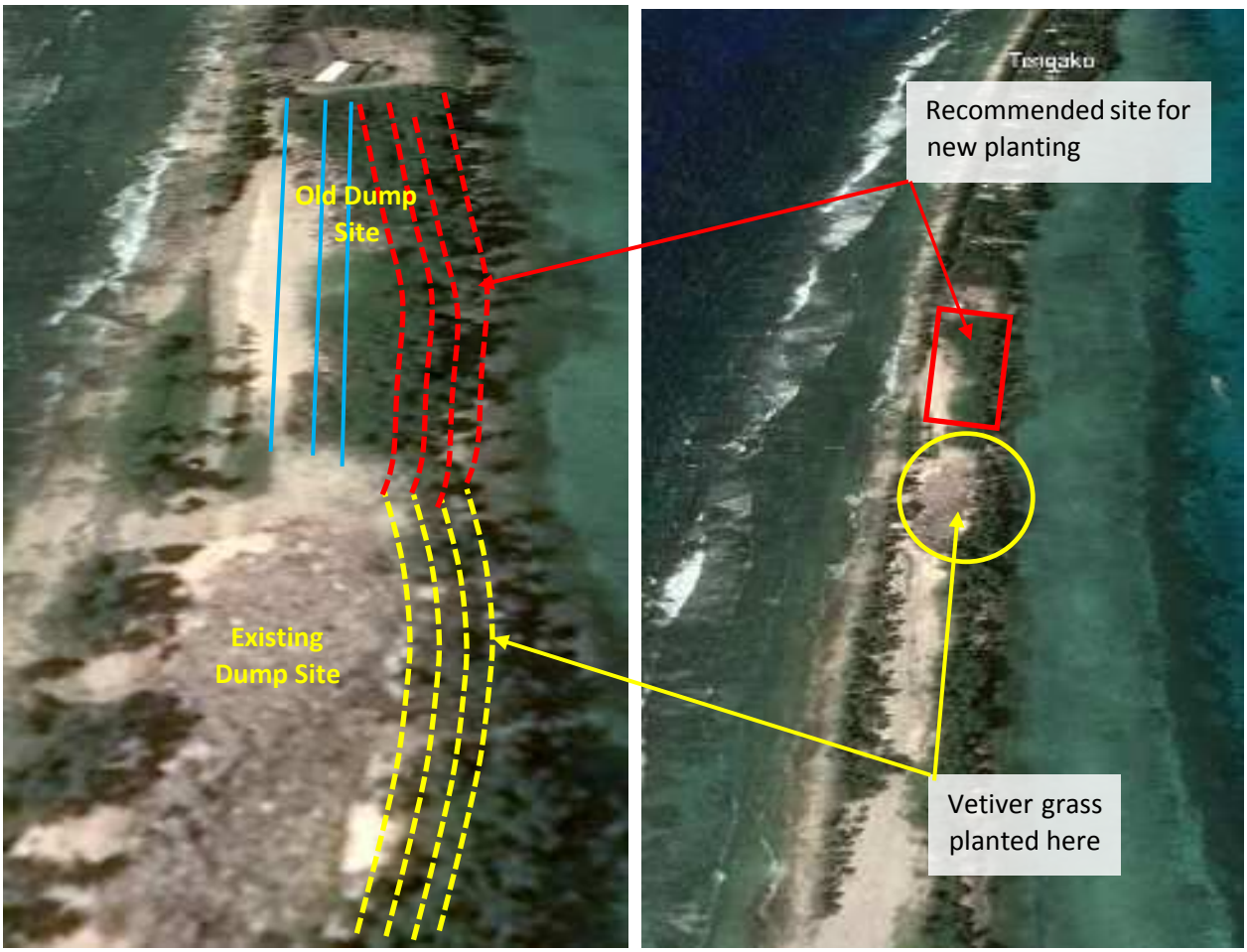
There are also multitude of benefits of Vetiver for the landfill on-site treatment and includes; (1) On-site leachate treatment and disposal, (2) it has low establishment costs (3) it has a faster growth rate, (4) high water usage, (5) maintenance cost is low and is multifaceted – addresses wastewater treatment, protects infrastructure, rehabilitates land, (6) controls erosion and sediment, (7) it is highly tolerant to adverse conditions and has the capacity to remove excess nutrients.

3.1 Baseline Water Quality Assessment Data

Date	Sample	Site Name	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	Phosphate (mg/L)	pH	µS/cm	GPS Latitude (°)	GPS Longitude (°)
14/9/18	1	Dumpsite	0.04	.05	0.02	0.02	8.16	52379.2	-8.45421 °	179.18105 °
14/9/18	2	Dumpsite	0.04	.06	0.03	0.02	8.16	52435.2	-8.45427 °	179.18097 °
14/9/18	3	Dumpsite	0.04	.06	0.02	0.02	8.13	52414.0	-8.45442 °	179.18077 °

Table 1: Water sample analysis (Data by Emma Newland – SPC)

It is necessary that regular water sampling be done to monitor the variations of water quality and to measure the effectiveness of the Vetiver System in treating wastewater.



Map 1 & 2: Imagery view of the Funafuti landfill site where vetiver grass was planted

Picture 3 & 4: The landfill site before planting of vetiver grass


Picture 5 & 6: Initial vetiver grass planting at the landfill site by the participants and school children from Fatuvalu High School.


Picture 7 & 8: Picture taken seven days after being planted

3.2 Key recommendations:

1. Continue to plant vetiver grass on the lower side of the landfill, along the lagoon side. Clear the shrubs, bushes along the coastline and continue from the four hedgerows planted where we left on the lower side of the landfill (refer map 1 & 2). These should start as soon the slips in the Agriculture nursery are ready for planting.
2. Vetiver also to be planted on the sand at reclaimed areas to form the first layer of defence against waves and also filter wastewater flowing to the lagoon. Further, after the Vetiver layer then native trees can be planted more inland (refer map 1).
3. Any reclaimed area after the landfill is full, should have vetiver planted on the sand.
4. Trash/smash very big wastes such as drums, vehicles, washing machines etc. before disposing of it into the landfill to avoid the landfill from filling up fast.

5. Segregate the green waste from the store rubbish and dump separately. The green waste can be used as composting soil mixed together with leave trims of the vetiver grass for family gardening.
6. Upscale to other landfill sites on the outer Islands as soon as more vetiver slips are propagated and are available.
7. Continue with water sampling analysis every three months to monitor any changes in water quality and algal growth.

4 Managing wastewater from piggeries at the Tafua Pond

The perimeter of the Tafua pond area is estimated to be 26,265m, and is located towards the Northern end of the Funafuti International Airport. It is lined with pig pens along the edges of the pond, the main source of the water pollution.

The piggeries along the Tafua pond produce hundreds of tonnes of waste water per day, including pig manure collected and washed down from slatted floors, which contain high nutrient loads. Consequently the washing down of these wastewater from the piggeries is a huge problem for this very important water source in Tuvalu. Therefore, a wetland is considered to be one of the most efficient way to reduce both the volume and high nutrient loads of piggery effluent. Since effective wastewater treatment requires year round growth, vetiver is one such plant identified to be suitable for wetland treatment (Liao, 2000).

Picture 9 & 10: Piggeries along the Tafua pond

Vetiver's usefulness in treating polluted water lies in its capacity to quickly absorb nutrients and heavy metals, and its tolerance to elevated levels of these elements. Vetiver's fast growth and high yield (dry matter production up to 100tns/ha/year) allows vetiver to remove a much higher volume of nutrients and heavy metals.

Treatment of these waste in the pond will be done hydroponically using the unique vetiver grass. An estimated hundred (100) pontoons is required to effectively treat the pond of its contaminants. These will be done pending new water analysis and monitoring of the four pontoons in the pond.

Picture 11-13: The Tafua pond highly contaminated with pollutants from the pigsties.

4.1 Baseline Data for Monitoring and Evaluation

Baseline data below will provide the minimum information to assess the quality of the activity implementation and help us to measure the development results of the water quality. The baseline data below will help us to monitor and evaluate our monitoring activity to see if there are any improvements to the quality of water.

The table below are Water Quality Assessment from a recent water sampling done at the Tafua pond.

Date	Sample	Site Name	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	Phosphate (mg/L)	pH	µS/cm	GPS Latitude (°)	GPS Longitude (°)
14/9/18	1	Tafua Pond 1	0.13	0.01	0.01	0.29	8.06	46026.2	-8.51925 °	179.20195 °
14/9/18	2	Tafua Pond 2	0.19	0.02	0.01	0.30	8.07	46040.1	-8.51924 °	179.20197 °
14/9/18	3	Tafua Pond 3	0.27	0.02	0.01	0.28	7.87	46067.7	-8.52049 °	179. 20103 °
14/9/18	4	Tafua Pond Mid	0.05	0.02	0.01	0.74	8.51	43510.7	-8.52232 °	179.20003 °

Table 2: Water sample analysis before vetiver treatment (Data by Emma Newland, SPC).

In this study, nitrogen was tested in the form of nitrate, nitrite and ammonia; and phosphorous in the form of phosphate. These species were included because they influence aquatic primary production - growth of benthic microalgae (periphyton), photosynthetic bacteria, phytoplankton, macroalgae, and aquatic vascular plants (Newland, 2018). However, there is likely going to be a setback as the results indicate the water is too salty for vetiver growth, it should be less than 11000µS/cm, result as shown is on an average of 46000µS/cm. Recommend further monitoring of the 4 pontoons to assess if it can withstand the salt level.

Further sampling is therefore recommended from other sites inland (refer annex 7 for the location of new sampling).

4.2 Cost Analysis for constructing pontoon

Four pontoons were constructed by the R2R Island Officers (refer picture 14-17) and launched into the Tafua pond (refer picture 18-21) as a training during the Education Awareness Campaign week. The 4 pontoons are insufficient to effectively treat the pond, therefore more pontoons are recommended. The launching of these pontoons into the pond was also a significant event for the Vetiver System Technology in the South Pacific, these project was the first of its kind in the region to use the pontoons for wastewater treatment.

The materials used and the cost of constructing the pontoons is shown in Table 3 below.

Material List	Qty	Unit Cost	Total Cost
PVC Pipe (100mm) – 5.6m	8	$ 40.00	$320.00
Equal T Junction (100mm)	8	$ 9.50	$76.00
90 Degree Elbow (100mm)	16	$ 9.50	$152.00
PVC Glue	6	$ 5.40	$ 32.40
Wire Mesh (Rust Resistant) 50m roll	1	$ 270.00	$270.00
3 inch nails	2 Pkts	$ 5.40	$10.80
Nylon Rope (200m@$1600 = $8/m) - Used 20m only	1 roll	$ 8.00	$160.00
Timber (2mx2mx5m)	8 pcs	$ 16.50	$132.00
Total Cost			**$ 1,153.20**

Table 3: Material listing and costing for the pontoons

The average cost of constructing five (5) pontoons (4 constructed, 1 yet to construct) is therefore AUD230.64, excluding the cost of labour. Average time taken to construct the four pontoons was seven (7) hours by four (4) people.

Picture 14 - 17: Construction of the Vetiver pontoons by the R2R Island Officers

Picture 18 - 21: Placing of vetiver grass onto the pontoon and launching into the pond.

Picture 22: Feagaiga Penivao in front of the vetiver pontoons

4.3 Key recommendations:

1. Water sampling analysis indicates the pond is too salty (average 45000µS/cm), vetiver can grow in waters less than 11000µS/cm. Further sampling of water from inland as indicated on annex 7 is required, and monitor growth of vetiver on the 4 pontoons if they can withstand before we proceed with other recommendations below.
2. Construct 96 more pontoons to bring the total number of pontoons for the pond to hundred (100). Tie then in groups of ten (10) pontoons, 1m between each pontoon. Place the pontoon rows five (5) meters apart from each other and anchor across the length of the pond. They can be easily moved to highly contaminated areas as and when water quality improves in the current location.
3. Pull the pontoons to the side of the pond for maintenance every six (6) months. Maintenance should include, leave trimming, removing of tillers for use in other applications, replacing and rusted or worn out materials that was used to build the pontoon.
4. For the construction of the other pontoons, geogrid matting is highly recommended as it is rust resistant and can last longer than the wire mesh. Wire mesh was used in these start up project due to unavailability of geogrid matting locally in Tuvalu.
5. Do water sampling test every three (3) months to monitor the progress of water quality.
6. Planting of the vetiver hedgerow along the edge of the pond near the pigsties does not look possible as initially thought due to the proximity of the buildings to the pond. It is therefore recommended the pigsties to be relocated to a centralised location, two rows

of vetiver hedgerows to be planted on the cleared site to remediate the contaminated land and revegetated for recreational use.

7. Pigsties built on other sites rather than the pond should have a mandatory row of vetiver planted around the building to capture any pollutants from leaching into the environment.
8. The young leaves are palatable to animals such as goats, pigs and cow, therefore any trimming of young leaves can be fed to the pigs to complement with the feed stocks from the shops.
9. Upscale to other ponds on the outer Islands based on the lessons learned from these project.

5 Using Vetiver System to Control Coastal Erosion

Land loss in Tuvalu through high sea level rise and coastal erosion is also a major problem. Due to the low elevation, the coastal zone is submerging and the erosion datum plane is rising. Coastal erosion is removing the finer sediment from the reef flats, beach and land, resulting in the beach sediment coarsening. Inappropriate human activities are some of the major contributing factors which triggers coastal erosion.

The land loss in Tuvalu is mainly caused by inappropriate human activities including coastal engineering and the recent aggregate mining, and cyclones are also contributing to these problem. There are evidences of eroding coastline with several coconut trees fallen down and sea eating its way into and around the trees which are still standing.

Picture 23-24: Fast eroding coastline on Fualopa Marine Protected Island.

Coastal protection is also one of the most serious need for the Tuvalu Atolls, therefore if we don't act now and build up our coastal protection, more land will be lost through erosion. Some coastal protection strategies may include building seawalls, planting mangroves and trees along the coastline, this however has proven ineffective and costly in many Small Island Nations.

According to a Pacific Climate Change Science Program study, since 1993 the sea level around Tuvalu has risen by 5 millimetres per year. It is anticipated by 2030, under a high emissions scenario, the rise is projected to be in the range of 7 to 18 centimetres. As reported, it is possible significant areas of the country will be submerged and uninhabitable, and communities forced to relocate.

Hence, the protection of Tuvalu's vulnerable coastlines is an urgent priority, therefore the protection of these coastlines using Vetiver System is of paramount importance.


Picture 25-26: Fallen trees and washed out beaches on Fualopa Island (Conservation Area). The Island needs protection from further beach erosion.

5.1 Key recommendations:

1. Plant four (4) hedgerows of vetiver starting from the Queens Park through to the Funafuti hospital (1.69km), only in sections where there are sandy beaches. This is to protect the coastline from eroding and also to act as a natural filter to treat wastes from household leaching into the lagoon. Inter row spacing at two (2) meters apart and plant spacing of six (6) slips per meter (Refer Annex 5).
2. Plant four (4) hedgerows of vetiver along the coastline, around the entire perimeter of Fualopa Marine Protected Island (Conservation Area). This site can be used as a pilot to trial out for the coastal erosion protection. Inter row spacing of two (2) meters apart and plant spacing of five slips per meter. Total lineal meter to be planted is 769m (Refer Annex 6)
3. All slips for planting for coastal erosion protection to be raised in either poly pots or in strips before planting out to the respective sites.

6 Summary

Tuvalu is facing a possible catastrophic future due to a perfect storm of climate change induced extreme weather events, and inadequate social and basic needs services from limited funding of government administration is resulting amongst others, serious food security and health problems, compounded by degenerating natural resources, soils, forest and inland and coastal water.

Adequate management of solid wastes, hence resulting in contamination of water sources in Tuvalu poses a significant challenge to the fragile Island environment. Therefore, improved waste management systems with more public awareness about the impacts of wastes to our environment, especially our water sources must be enforced and carried out. Sustainable financial mechanisms are needed to ensure that waste management activities implemented by the Ridge to Reef team continue in the medium to long term.

Vetiver grass having some very important properties, makes it more useful for wastewater treatment and environment protection in the atolls of Tuvalu. The Vetiver System Technology being cost effective, self-sustainable, environmentally user-friendly, having the ability to grow on any soil type such as sandy soils, sand and coastal areas with root growth growing to more than 3 meters and proven to absorb nutrients from waste water including nitrogen (up to 94%) phosphorus and potassium (up to 90%) makes it a favourable choice of grass to be accepted and applied to all sites of concern as recommended.

As a remedial measure, one part of the solution are the introduction of low cost and relatively simple technologies that can help build resilient “do it yourself” communities both in rural and urban areas. One such technology is the use of Vetiver System Technology – the Proven and Environmental Green Solutions for the atolls.

We must manage the problem, and not the problem managing us, the least is the most expensive and it comes with a price tag.

7 References

Chomchalow, N. The Role of Vetiver in Controlling Water Quantity and Treating Water Quality: An Overview with Special Reference to Thailand* AUJ.T. 6(3): 145-161 (Jan. 2003)

Iese, V; and N'Yeurt A. 2018. Final Report for Seaweed Monitoring Survey in Tuvalu

Newland, E. 2018. Water Quality Assessment of Fongafale Lagoon, Tuvalu

Truong, P. 2002. The global impact of vetiver grass technology on the environment. Proc. ICV-2, ORDPB, Bangkok, Thailand.

Truong, P.; and Hart, B. 2001. Vetiver System for Wastewater Treatment. Tech. Bull. No. 2001/2, PRVN/ORDPB, Bangkok, Thailand.

Truong, P. Clean Water Shortage, an Imminent Global Crisis. How Vetiver System can reduce its Impact

Woodruff, A. Solid Waste Management in the Pacific. Tuvalu Country Snapshot

Xue, C. Causes of land loss in Tuvalu, a small island nation in the pacific. Journal Vol. 4. Issue 2 (April. 2005)

8 ANNEX 1: R2R Vetiver Planting Training Report

RIDGE TO REEF MISSION REPORT: VETIVER PLANTING TRAINING

Mr Robinson Vanoh 16th – 30th October, 2018

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Introduction

Vetiver implementation and rollout program was a follow up from our last training done on the 20th – 21st of April 2018. These was based on recommendations by the recent survey in 2017 funded by the Tuvalu Ridge to Reef Project (R2R) team due to algae bloom (*Sargassum polycystum*) at the Funafuti lagoon that was visible in 2012 which has caused severe impacts on people and the environment and coastal ecosystem of Funafuti atoll. Also follow-up studies conducted over time since 2013 concluded that the wastewater pollution was mainly from land-based sources such as household sewage seepage, waste dumping sites, and from vessels visiting the Funafuti lagoon (ballast, wastewater disposals).

The Tuvalu Ridge to Reef Project requested a technical team from Suva (Mr. Viliamu Iese (VI) and Dr. Antoine de Ramon N'Yeurt (ADRN)) to conduct a special training to analyze water quality data collected by the field team. Also technical expertise were requested during the mission to initiate the implementation of the Vetiver System Technology, which is one of the "green solutions" for wastewater management. During the mission, 300 bare rooted Vetiver slips were collected from Fiji and initial stock start-up nursery was started both at the Department of Agriculture nursery and the Funafuti Kapule nursery.

The Tuvalu Ridge to Reef Project (R2R), again requested for technical expertise to implement and rollout the Vetiver planting project for the Funafuti Landfill site and the Tafua pond during the Education Campaign week. Primary responsibility for the technical expert was to support the Tuvalu Ridge to Reef Project in implementing the remedial measures for the issue of algal bloom in Funafuti lagoon.

Scope of Work key responsibilities in the Terms of Reference for these mission was to provide Technical Advice in:

1. Taking the leading role in organizing and conducting training on Vetiver planting for locals and key stakeholders.
2. Provide training materials (manual) for the training.
3. Provide assistance in constructing planting materials (pontoon) for Tafua pond.
4. Leading role in planting of Vetiver to designated sites (dumpsite and Tafua pond).

The expected Outputs and Deliverables were:

1. Training material/manual for Vetiver planting.
2. Training report for Vetiver planting training.
3. Mission Report.

The Vetiver training and implementation coincided with the R2R Education Campaign from the 23rd to the 27th October, 2018. Training of the R2R Island Officers was conducted at the **Vaiaku Falckau Pule** on Friday, October 19th, 2018. Procuring of materials for the construction of the pontoon for the Tafua pond was done on Saturday, 20th, 2018 and training and construction of the pontoon was done on Monday, October 22nd, 2018. On site planting and training at the Funafuti landfill site was done on Wednesday, October 24th, 2018 followed by on site planting training and launching of the pontoons into the Tafua pond on Saturday, October 27th, 2018 after PowerPoint presentation of the Vetiver System Technology at the Government conference room.

Given below are a brief summary of the training, activities and consultations that took place during the Tuvalu Mission.

Training Locals and Relevant Stakeholders on Vetiver Planting

TRAINING OF ISLAND OFFICERS

The first training session was conducted on Friday, October 19th for the Island Officers from the outer Islands at the Community hall. The training session included power point presentation, issuing out of Vetiver posters, viewing of video on Coastal erosion, handicraft making and an animated video on Vetiver.

No.	Name	Gender	Designation	Island
1	Lopati Samasoni	M	Island Officer	Nanumea
2	Antieu Haleto	F	Island Officer	Nanumaga
3	Leafaga Vaiutu	F	Island Officer	Niutau
4	Rooko Ipitoa	F	Island Officer	Niu
5	Bailey Koulapi	M	Island Officer	Vaitupu
6	Lila Fousaga	F	Island Officer	Nukufetau
7	Manao Stanley	M	Island Officer	Funafuti
8	Lanu Latonum	F	Island Officer	Nukulaelae

Table 1: List of participants who attended the training session.

Picture 1: Island Officers from the outer Islands during our training session.

PAGE 3

Our training session was mainly on propagation and management of the Vetiver grass. Following are what we covered during our training session:

The two (2) common ways to propagate Vetiver which includes (1) Splitting of mature tillers from Vetiver clump or mother plants for immediate planting or propagating in polybags, and (2) Using of various parts of a mother Vetiver plant.

Splitting of tillers from a mother clump requires care, so that each slip includes at least two to three tillers (shoots) and a part of the crown. This was further demonstrated with the Vetiver grass taken from our stock nursery. It is recommended that for the Atolls, it is necessary to raise all our planting stock in poly pots and strips for our projects.

Picture 2 & 3: Bailey with sample of the two months old Vetiver grass. On the left is after it was taken off from the poly pot and on the right is after shaking off the sand from the roots.

Participants were also taught of the different parts of the Vetiver plant that can also be used for propagation and that includes:

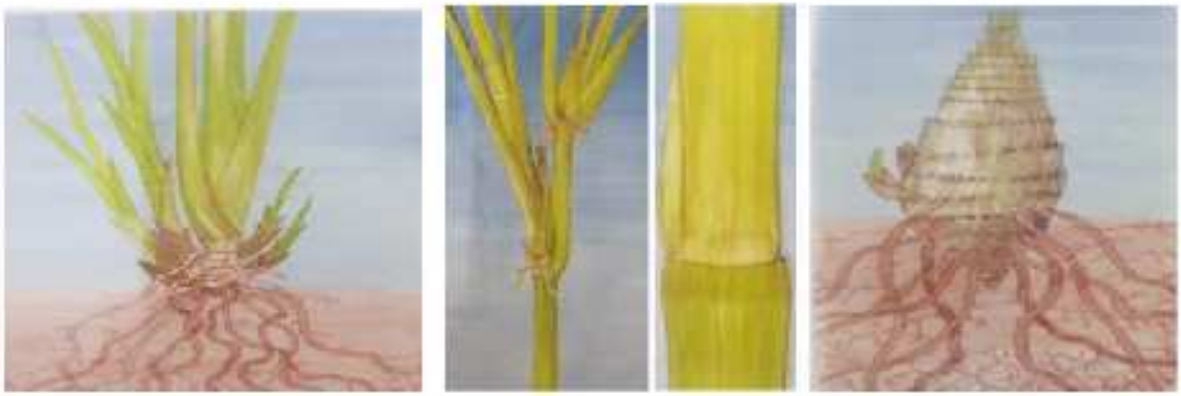

Diagram 1-3: The different parts that are used for propagation, from left to right, Tiller, Culm (stalk or stem) and the crown.

Disadvantages and advantages of using bare rooted slips, planting strips and poly potted plants were also explained further. Following are some of the disadvantages and advantages that we discussed.

For bare rooted slips the advantages are (1) efficient, economic, and a quick way to prepare the planting material, (2) easy to plant by hand and less volume for transportation. The disadvantages are; (1) they are vulnerable to drying under extreme temperatures, (2) limited on-site storage time, (3) requires planting in moist soil, and (3) needs frequent irrigation in the first few weeks after planting.

For the strips and poly potted, their advantages are; (1) plants are hardy and unaffected by exposure to high temperature and low moisture, (2) lower irrigation frequency after planting, (3) faster establishment and growth after planting, (4) can remain on site for longer before being planted and (5) it is recommended for harsh and hostile conditions. The disadvantages are; (1) more expensive to produce, (2) preparation requires a longer period to prepare, (3) transporting large volume and increased weight is expensive and (4) increased maintenance cost following delivery, if not planted within a week.

PARTICIPANTS COMMENTS AND FEEDBACK – EVALUATION

Training Evaluation by participants

The following data were collected from the participants of the training.

No. of Participants Evaluated	7
Participants Evaluated (%)	100

Questions	1	2	3	4	5	Total
The objective of the training were met					7	7
The presenter was engaging				1	6	7
The presentation materials were relevant					7	7
The content of the training was organised and easy to follow				1	6	7
The trainer was well prepared and able to answer any questions					7	7
The training length was appropriate					7	7
The pace of the training was appropriate to the content					7	7
The excreises/demonstrations were helpful and relevant					7	7
The venue was appropriate for the event		2	1	2	2	7

Table 1: Data from evaluation of the training

Observations and lessons learned from the training

- Demonstration on the different parts used for propagation and also the importance of Vetiver grass to our environment and its economical values.
- More on other uses of the Vetiver grass.
- Training to include Island officers and to be community based because of its usefulness.

Recommendations for further improvement/follow-up actions

- Further training is requested for some more Island officers to be trained.
- Set up demonstration sites on each Atoll to train locals.

Training on How to Construct Vetiver pontoon

Sourcing and procuring of the materials for the construction of the pontoons was done on Saturday, October 20th 2018 by Elu and myself. All the materials required for construction of the pontoons were obtained locally. Demonstration and training on how to construct the pontoons was carried out the at Feagaiga's residence on Monday, October 22 2018.

Following is a list of attendees for the pontoon construction and training.

No.	Name	Gender	Designation
1	Feagaiga Peniuao	M	LMMA Officer
2	Bailey Koulapi	M	Vaitupu Island Officer
3	Manao Stanley	M	Funafuti Island Officer
4	Malau Akelisi	M	Niulakita Island Officer
5	Elu Tataua	M	Project Support Officer

Following pictures are demonstrations of how the pontoons were constructed during our training.

Picture 4 & 5: Feagaiga demonstrating how to measure out and mark the PVC pipe for cutting.

Picture 6 & 7: Bailey demonstrating how to cut the PVC pipe.

Picture 8 - 11: PVC pipes cut out to measurement and applying of PVC glue for joining.

Picture 12 & 13: Fitting together of the PVC pipes and fittings

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Picture 14 & 15: Manao showing off his completed pontoon (L) and construction of timber frame for the wire mesh fitting.

Picture 16 – 18: Measuring out the wire mesh, fitting onto the timber frame and the completed pontoon.

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Training and on-site planting demonstration (Funafuti Landfill)

The Funafuti landfill site was identified to be one of the sites with high level of water contamination from the leachate from the wastes dumped. Prior to training, on site visit was done on Tuesday, October 23rd after the morning session by all the participants. After identifying the site for planting, planting layout and site preparation was explained to the participants for the next day's planting program. The site identified for planting at the edge of the landfill is towards the lagoon.

Picture 19 & 20: The site for the Vetiver planting towards the lagoon side, low side of landfill.

Planting material to be used for the site was delivered on Wednesday, October 24th. All the Vetiver grass used at the site was raised in both Agriculture Department nursery and in front of the office at Partnership House.

Picture 21 & 22: Vetiver at the nursery (left) Partnership house (right) Agriculture Department nursery


Picture 23 & 24: Transportation of Vetiver to the site for planting.

The planting of the Vetiver grass was done on Wednesday, October 24th by all the participants. Form three (3) students from Fetuvalu High School also participated in the planting. Field demonstration on how to prepare furrow, apply fertilizer and planting of the slips were done during the planting process. Total of 319 Vetiver plants were planted on the landfill site.




Picture 25 – 28: Vetiver grass planting at the Funafuti landfill site.

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PowerPoint presentation on Overview of Vetiver System

Presentation on the overview the whole Vetiver system was presented to the participants by Elu Tataua followed by question session. Participants asked series of questions in regards to the Vetiver grass and its uses. Participants asked if the grass was invasive, how long can the grass can last after being planted, are there any disadvantages and how to prepare roof thatching.

No.	Name	M/F	Organization	No.	Name	M/F	Organization
1	Petaia Paeni	M	Nukulaelae	25	Seima	F	Nukulaelae
2	Eleisama F	M	NKF	26	Lovine I	F	Nui
3	Robinson Vanoh	M	TVNI	27	Alalu	F	Nanumaga
4	Malau A	M	R2R Niulakita	28	Bailey	M	Vaitupu
5	Tongia	M	Nanumaga	29	Mose I	M	VTP Kapule
6	Manao Stanley	M	Funafuti	30	Seloha	F	Agriculture
7	Roko Ipotoa	F	Niu R2R	31	Elu Tataua	M	R2R
8	Lila T	F	R2R	32	Tesaa	M	VTP
9	Falani	M	Nukulaelae	33	Mesela	F	VTP
10	Ivy Latasi	F	R2R	34	Faoliu T	F	Environment
11	Kiuti S	M	Nukufetau	35	Lynn	F	Niulakita
12	Leafagatuagi V	F	Niu IO	36	Marianne V	F	Environment
13	Holipai K	F	Niu	37	Vegaimo P	M	Environment
14	Fitipilipa Fai	F	Nukufetau	38	Asenati M	F	Funafuti
15	Paeagi	F	Nanumea	39	T Liveli	F	Takitaki Alapi
16	Lopati Samasoni	M	Nanumea IO	40	Lanu	F	NKL
17	Aocte Makail	M	Pule Kaupule	41	Leafaga	F	Niutao
18	Teipe	M	Niulakita	42	Semese Alelaio	M	TFD
19	Laluta K	M	Malosiga				
20	Tili K	M	Kaupule				
21	Siliga	M	Funafuti				
22	Lilo	F	Nanumea				
23	Feagaiga Penivao	M	R2R PIU				
24	Teolu	F	Niulakita				

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Picture 29 & 30: Delivering of presentation to the participants by Flu Tafuna

Planting and Launching of the Vetiver Pontoons at Tafua pond.

Training on Vetiver planting in the pontoon and launching of the Vetiver pontoon was done on site at the Tafua pond by all the participants. The pond (refer picture 31) is highly contaminated with waste from the pig sties as evident with the blue green algae growth. The Vetiver grass on the floating pontoon with its ability to uptake nutrients will clean up the pontoon. Only four pontoons were built and launched into the pond for demonstration. It was explained that further pontoons will have to be built to cater for the capacity of the pond. Total potted Vetiver slips placed in the pontoon was 200, which is 50 slips on each pontoon.

Maintenance of the pontoons is also necessary every three months, after maintenance it can be relocated to areas where it is highly contaminated.


Picture 31 & 32: The Tafua pond (left) and delivering of poly potted Vetiver slips for the pontoon.


Picture 33 & 34: Team work by all participants in moving slips to be placed in the pontoons.


Picture 35 & 36: Placing of Vetiver grass into the pontoons


Picture 37 & 38: Launching of the Vetiver pontoon into the Tafua pond.

Summary

The Tuvalu Ridge to Reef Education Campaign week hosted from the 23rd – 27th October was very informative with lots of role plays, site visits and activities. The theme of the campaign was "Caring for Nature is Everyone's Responsibility".

The Vetiver planting and pontoon construction training coincided with the Campaign week, which included; training of Island Officers on propagation and management of Vetiver grass, site preparation and planting of Vetiver grass at the Funafuti landfill, power point presentation on the overall view of the Vetiver System Technology and the construction of Vetiver pontoons and launching into the Tafua pond.

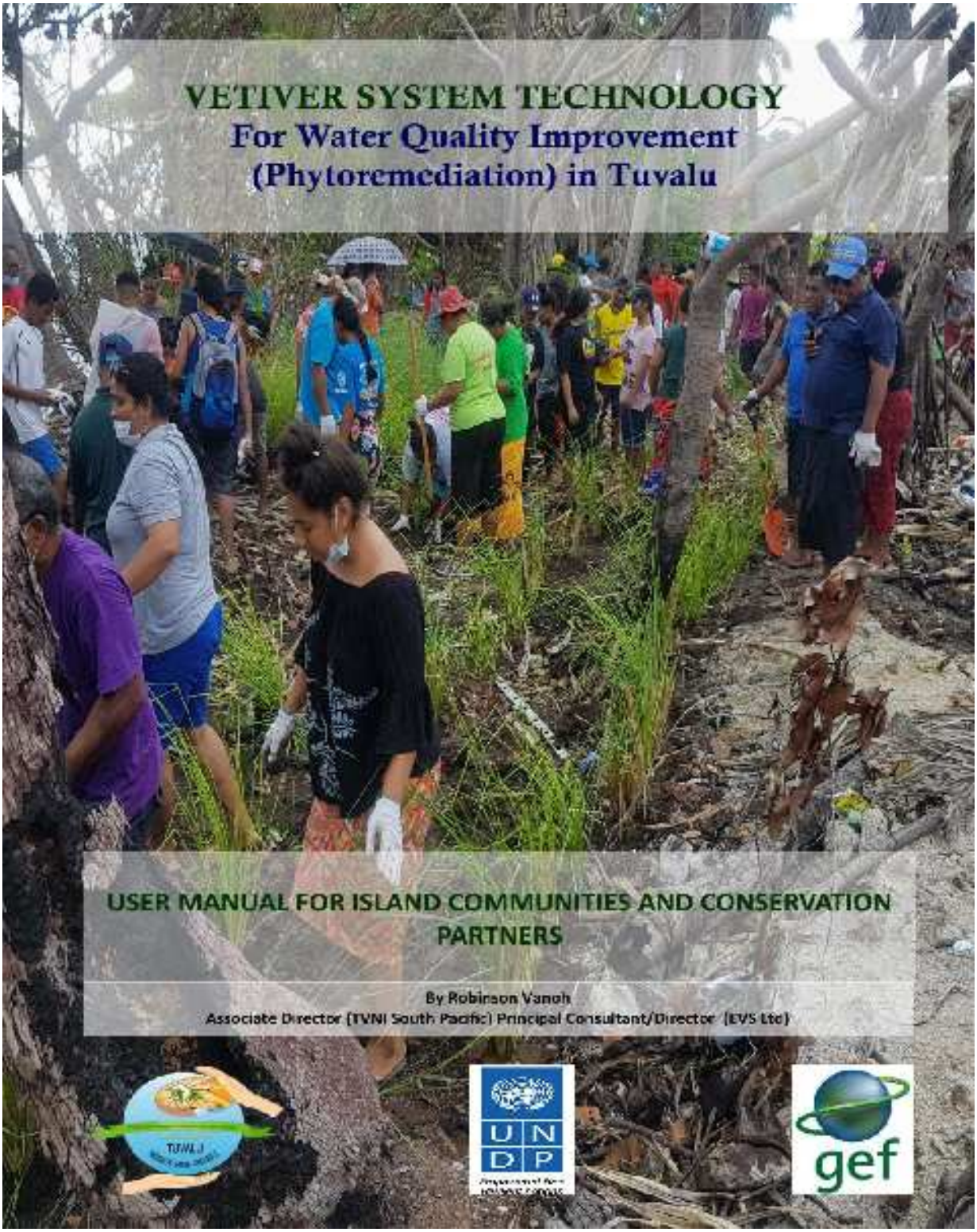
The physical activities involved in the Vetiver planting program was used as a learning experience for many participants who did with great interest and enthusiasm. The team effort by all the participants and that includes the form three (3) students from Fetuvalu High School was commendable.

PowerPoint presentation on the general overview of the Vetiver System, which was translated into Tuvaluan language and presented by Elu Tataua was also received well by the participants. Many questions of interest were asked by the participants, which I had the opportunity to have it answered after the question was translated to me by Elu.

Further hands on training of more Island Officers, school children and the local communities will broaden the knowledge base for further up scaling to the outer atolls from the lessons learned from the Funafuti pilot project.

I highly commend the Tuvalu Ridge to Reef team for a well-coordinated campaign week, I believe from the lessons learned from the campaign week, each participant will have the drive to now embrace the theme "Caring for Nature is Everyone's Responsibility".

9 ANNEX 2 – User Manual for Island Communities & Conservation Partners



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INTRODUCTION

Research conducted in several countries has demonstrated that Vetiver grass has a very high rate of nutrient uptake under both dry land and wetland conditions. In addition, due to its origin as a wetland species, Vetiver grass also flourishes under hydroponic conditions, where its fine and extensive root system is very active in absorbing nutrients particularly Nitrogen and Phosphorus. Taking advantage of these unique characteristics, Vetlcon Consulting developed a floating system to purify polluted or contaminated water since 1995. To date the technique of using floating pontoons to treat polluted water has been used successfully in several countries in Australia, Asia and Africa and the Americas. In Australia the pontoon system has been used successfully to treat sewage effluent and industrial wastewater. In China it was used to treat polluted water in lakes and rivers polluted with N and P. In China and Vietnam it was used very effectively to treat piggery effluent.

Two years old Vetiver root — PNG

GLOBAL WARMING

Global warming is a phenomenon arising from the burning of fossil fuels like petrol, coal, and natural gas, which have been buried underground for millions of years. Burning of these fossil fuels, together with additional burning of wood in the process Of deforestation results in the release of large amounts of carbon dioxide (CO_2), which ultimately forms a layer in the atmosphere. Such layers act as a greenhouse effect, in not allowing the heat from sun to shine on the earth, which normally reflects back to the atmosphere, but instead bounds back to the earth. This raises the temperature of the earth by several degrees Celsius. This is known as the 'Greenhouse Effect'. These effects on the environment hence resulting in the so many problems is evident on all the atolls to Tuvalu.

"Water is one of the most important natural resources of mankind. Its importance must be appreciated."

PROBLEMS RELATED TO WATER

Problems related to water are of two main types. Quantity and Quality. Their nature is described below, while the role of Vetiver in controlling them will be discussed in the subsequent sections.

Water Quantity:

Thousands of people suffer from severe floods. Hundreds of people drown; similarly thousands of livestock also die of the same cause. The effect on crops are beyond comprehension. This causes a similar problem of the same factor, i.e. water quantity. But more importantly and more common is the unavailability of quality water is a phenomenon throughout the developing nations.

Recent survey conducted by Tuvalu R2R indicates contamination of water from land sources is vey high resulting in the algal; bloom.

Protecting a water source using Vetiver.

WATER QUALITY

Vetiver planted at edge of farm drains to protect water from being polluted with agrochemicals

Water quality signifies the absence of contaminants, which are waste products, pollutants and nutrients. Depending upon the usage, the presence of Some contaminants in the water may be acceptable; e.g. water that is used for agricultural and other activities may not need to be pure. While that presence in a lake or other bodies of water should not be rich in nutrient, otherwise, a phenomenon of eutrophication will occur, resulting in algal Bloom and the depletion of oxygen in the water, which results in the death of aquatic life. However, water for human consumption should be as clean as possible, i.e. uncontaminated with pathogens, nutrients, heavy metals, and other toxic or hazardous substances.

VETIVER AND WATER

"Vetiver, a humble grass, has a big role to play along with this major natural resource."

Vetiver has a major role to play along with water for treating wastewater in Tuvalu. This is most appropriate in the present circumstance, when water is the most important natural resource for Tuvaluans. Vetiver, a humble grass, has a big role to play along with this major natural resource. It is an essential tool in mitigating this pending water crisis affecting Tuvalu.

Vetiver pontoon on the Tafua pond (Funafuti)

INTERDEPENCE OF VETIVER AND WATER

Vetiver and water are interdependent on each other. As other living creatures, Vetiver depends on water for its growth and development. However, in terms of quantity and quality, the availability of water, depends to a certain extent on Vetiver. Vetiver helps to regulate the amount of water. It conserves water when water is scarce. It helps to reduce surplus runoff rainwater by spreading it perpendicularly along the contour hedgerows, allowing much smaller amounts to pass through, while other amounts seep through the soil and retained by soil profiles, while the surplus after saturation, is stored as underground water in the aquifer. At the same time it also helps to purify contaminated or polluted water. Vetiver will play an important role in mitigating the current problems affecting Tuvalu.

SPECIAL CHARATERISTICS OF VETIVER

Veriver has many special characteristics that lend support for its uses in solving the water problems such as in the lagoons of the Atolls in Tuvalu. According to Truong and Baker (1998) and Cull et al. (2000), these can be classified into morphological and physiological characteristics.

Morphological Features

Vetiver has:

- Stiff and erect stems that can stand up to high velocity flows and increase detention time.
- Thick growth forming living porous barrier that acts as a very effective filter trapping both fine and coarse sediments, as well as sediment-bound contaminants (e.g. heavy metals and some pesticide residues).
- Deep, dense and penetrating root system, that can reduce and prevent deep drainage, and improve bed stability and nutrient uptake.
- Finely structured and massive root system, which provides an environment that stimulates microbiological processes in the rhizosphere.

"Vetiver has a deep, dense and penetrating root system."

Picture 1 & 2: Vetiver rooting biomass—excavated root in Vietnam (Left).

Physiological Features

Vetiver is:

- Highly tolerant to adverse climatic conditions such as frost, heat wave, drought, flood, and inundation.
- Highly tolerant to adverse edaphic conditions such as high soil acidity and alkalinity; saline, sodic, and magnesic conditions; and aluminum and manganese toxicities.
- Highly tolerant to elevated levels of heavy metals such as arsenic, cadmium, copper, chromium, lead, mercury, nickel, selenium, and zinc.
- Adaptive to be used in areas where too much water prevails, as it is able to consume high amount of water.
- Able to tolerate flood, making it ideal for use in ephemeral or permanent wetlands.

"Vetiver is highly tolerant to adverse climatic conditions, edaphic conditions and elevated levels of heavy metals."

Picture 3 & 4: Vetiver growing on highly caustic lower soil—Bauxite mine residue sand (Australia)

THE ROLE OF VETIVER IN TREATING WATER QUALITY

Water may be contaminated through various activities: agricultural, domestic, or industrial. There are two main measures to keep water uncontaminated or clean, namely 'prevention' and remediation'.

The Tafua pond in Funafuti

Prevention Measures

As in the case of human health, when dealing with the contamination of water, prevention is better than the cure. If at all possible, the Vetiver system should be employed as a measure in preventing water body from being contaminated. It should be emphasized that this prevention measures work through the removal of liquid-borne contaminants before entering the water body, otherwise, the measure is considered 'remediation', which removes these contaminants after they have been present in the water body. Currently two main methods of treating contaminated water, namely 'Engineering' and 'Biological', are being used. The biological method consists of land-irrigation, wetland, and hydroponic systems. Each system works through the removal or trapping/filtering of contaminants present either in: (a) the Leachates liquid leached from garbage landfill, quarry, farmland, etc.), or (b) the effluents (wastewater from septic tanks, city sewage treatment plants, plant nurseries, feedlots, cattle sheds, slaughter houses, piggeries, etc.). Note: the terms, 'leachates' and 'effluents', are used here to mean any liquid containing contaminants prior to becoming the main water body. If the latter is the case, purification process is considered 'remediation'.

"Prevention is better than cure—the latter is costly."

Diagram 1: Sources of waste generation into main water body.

LAND IRRIGATION SYSTEM

This system employs Vetiver plants grown as a crop to dispose both the large effluent volume and to strip soluble elements (particularly N and P) or filter sediment-bound chemicals. A computer model MEDLI (Model for Effluent Disposal by Land Irrigation), using pasture species, is being used by the Environmental Protection Agency (EPA) in Queensland, Australia to regulate effluent disposal from various industries including sewerage treatment plants, abattoirs and food processing plants. Veticon Consulting has developed a model specifically for Vetiver Grass (EDVI and EDVI-2 for small volume input.

Picture 6: Vetiver wetland in Boonah (QLD Australia)

Leachates

"Strip of Vetiver hedgerows will not only prevent seepage, but would act as a barrier to the movement of contaminants by wind or other means."

Agricultural Leachates: Modern cultivation of crops requires the application of fertilizers, growth substances, pesticides, etc. to promote crop growth and protect it from the attack of their enemies. Not all substance is absorbed by the crops, however, the surplus is leached from the farmlands. Sooner or later, it enters into the body of water. Residues of agricultural leachates, particularly pesticides, create a serious problem o the environment as they adversely affect flora and fauna in downstream aquatic ecosystems.

Picture 7: Garbage landfill on Funafuti Atolls

Industrial Leachates: Industrial waste dumps such as tanneries, galvanized and electrolytic factories are usually contaminated with heavy metals such as As, Cd, Cr, Hg, Pb, and Zn. Similarly, leachates from the quarries also contain high amounts of several heavy metals. As the heavy metals are toxic to humans, their removal from the leachates must be done prior to their entering into the water body.

Garbage landfill leachates: This is a special type of leachates which may contain nitrates and phosphates as in domestic leachate, or pesticide residues as in agricultural leachate, and particularly heavy metals and other hazardous substances as in industrial leachate, depending on what constitutes the garbage. In many large cities, garbage is deposited as landfill to decompose. Such landfills produce leachates that contain various matters, including heavy metals and other toxic substances. One approach to use vetiver to trap these harmful substances is to grow in a strip around the garbage landfill. Strip of vetiver hedgerows would not only prevent seepage, but would act as a barrier to the movement of contaminants by wind or other means.

Effluents

Effluents are wastewater with certain amounts of contaminants. They are classified as: (i) domestic, (ii) agricultural, and (iii) industrial effluents. They usually contain high amounts of nutrients particularly nitrates and phosphates, which will cause environmental problem if they are drained into streams or body of water.

Domestic effluents:

There are two kinds of domestic effluents 'black' and 'grey' waters. The former is sewage of the toilets while the latter is washing water from kitchens and bathrooms. If planted to intercept the flow of such effluents, Vetiver would prevent the effluent from reaching the water body. In addition, Vetiver would help dry up the effluent. Under these conditions Vetiver will grow extremely well and will remain green throughout the year.

Agricultural effluents:

These effluents are produced from various agricultural activities. Plant nurseries, feedlots, piggeries, dairy sheds, chicken houses, slaughterhouses, etc., produce a large quantity of such effluents that are oozing onto nearby land and into streams and ditches. If Vetiver grass were planted to intercept the flow of such effluents, it would do much to stop the effluent reaching water body and drying up the mess. Vetiver would grow extremely well and will remain green throughout the year.

Industrial effluents:

Using the EDVI model mentioned above, Vetiver was used successfully to treat 2.2 million litres of effluent (160mgN/L and 55mgP/L) discharged from food processing plant near Beaudesert, QLD. A total area of up to 64ha was used for Vetiver planting on this site.

Domestic effluent

"Effluents are wastewater with certain amounts of contaminants."

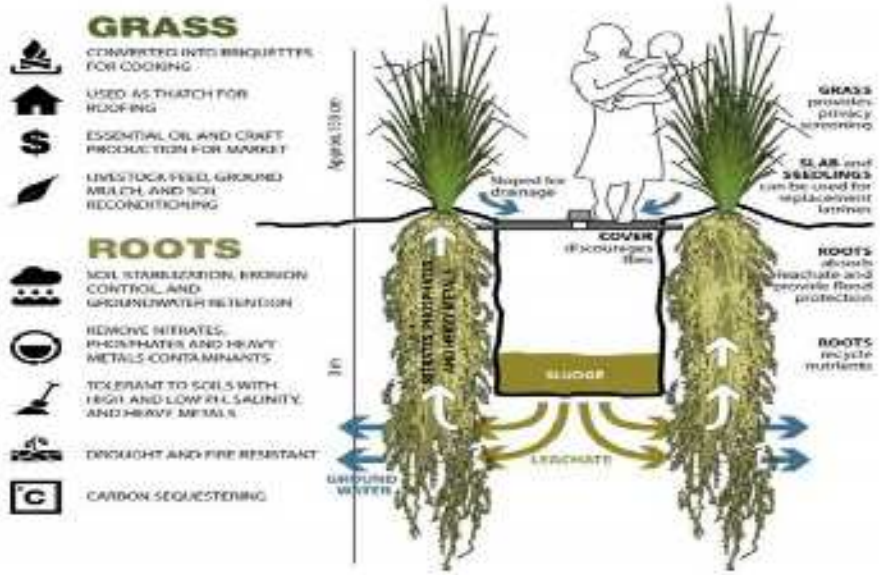


Diagram 2: Illustration of how the Vetiver System treats leachate in Eco Toilet (Bottomless pit toilets).

Roots at 2 months under hydroponic conditions.

HYDROPONIC SYSTEM

Using a floating platform, Vetiver can be grown hydroponically in the water with its root immersed in the water. Hydroponic system can be used to remove contaminants from leachates or effluents, which are drained into the pond or lakes. The advantages of this system using platform method is that Vetiver tops can be harvested easily for use as livestock feed, mulch, mushroom growing, etc.,

Picture 8: Vetiver hydroponic system.

Leachates

Due to practical difficulty in draining leachates into a pond and often high salinity, there has so far been few attempts to use Vetiver growing on the floating platform to remove nutrients, heavy metals, or toxic substances from the leachates

"Landfill Leachate: A potential Environmental Emergency."

Diagram 2: Flow of leachates from domestic landfill into the environment

Effluents

In theory, Vetiver grown on floating platforms can be used to remove nutrients, heavy metals, or toxic substances from effluents of various sources. However, only domestic effluents have been attempted. To determine the efficiency of Vetiver in improving the quality of domestic effluent, a hydroponic trial was conducted using a mixture of black and grey waters (Truong and Hart (2001). Their results confirm the Chinese research in that Vetiver could remove most soluble N and P in effluent over a very short period of time, and thus eliminating blue-green algae in the eutrophicated water

REMEDIATION MEASURES

Remediation is defined as "the process of remediating or cleaning up deteriorated, contaminated or intoxicated soil and water". If microorganisms are used to remediate, the process is called 'bioremediation'. The use of plant to clean up deteriorated, contaminated or intoxicated soil and water is called 'phytoremediation'. however, the term 'remediation' is generally used even when plants are used to clean up contaminated water.

Picture 9: Use of plant (Vetiver) to remedying contaminated water

Remediation: "The process of remedying or cleaning up deteriorated, contaminated or intoxicated soil and water".

Kind of contaminated water

In the case of a body of water, which has already been deteriorated, contaminated or intoxicated, purification can be done by removing contaminants from the body of water. Many terms have been used in the literature to describe the nature of liquid-borne substances that contaminate the water, such as wastewater, polluted water, and eutrophicated water.

Wastewater:

Wastewater is one that contains the liquid-borne waste products (organics, solids, and nutrients) of domestic, agricultural, and industrial or manufacturing activities. It is similar to eutrophicated water (see later), especially in the presence of plant nutrients such as N and P which favor the growth of algae; however, wastewater can also contain other organic and solid matters. Apart From the odor, the health risks created by this waste are enormous and include the source of typhoid and dysenteric diseases as well as breeding grounds for mosquitoes. Where the residencial areas have no drains, no potable water, no paving, water and sewage stagnate adding to the misery of living conditions (Grimshaw, pers. comm.).

Depending on the origin, three kinds of wastewaters are known, namely:

(i) Domestic wastewater: This is the water derived from human domestic activities, such as water from toilet (also known as 'black water'), sink, shower, and kitchen flows; and water used in washing or flushing (also known as grey water').

(ii) Agricultural wastewater: This is the water derived from agricultural activities, mainly from fertilizer application and secretion.

(iii) Industrial wastewater: This is the water derived from industrial or manufacturing activities, mainly of organic origin, and excluding those that contain harmful substances of inorganic origin.

Landfill leachate

Polluted Water

Fish in a polluted water

Polluted water is water contaminated with harmful substances resulting from agricultural and industrial processes. Such substances include (i) heavy metals, e.g. Pb, Hg, Cu, Cd, Cr, As, (ii) pesticide residues, e.g. insecticides, fungicides, herbicides, (iii) other harmful compounds. Upon entering into water body, elevated concentrations of these toxic substances pose a significant risk to human and animal health. Depending on the origin, polluted water can be classified into domestic, agricultural and industrial polluted water.

"The character of eutrophicated water is the promotion of algal growth due to the presence of high amounts of N and P"

Eutrophicated Water

Eutrophicated water is one which is rich in mineral and organic nutrients that promote a proliferation of aquatic plants, especially blue-green algae consuming nearly all the oxygen, especially during warm weather, choking the fish, and often causes the extinction of other organisms. The characteristic of eutrophicated water is the promotion of algal growth due to the presence of high amounts of N and P. Depending on the origin, it can be classified into domestic, agricultural, and industrial eutrophicated water. It should be noted that these three terms are closely related and can be used almost synonymously. Another term that is used to include all three is 'contaminated water', which implies impurity of the water without specifying the kind of contaminants, whether they are waste products (wastewater), harmful substances (polluted water), or nutrients (eutrophicated water).

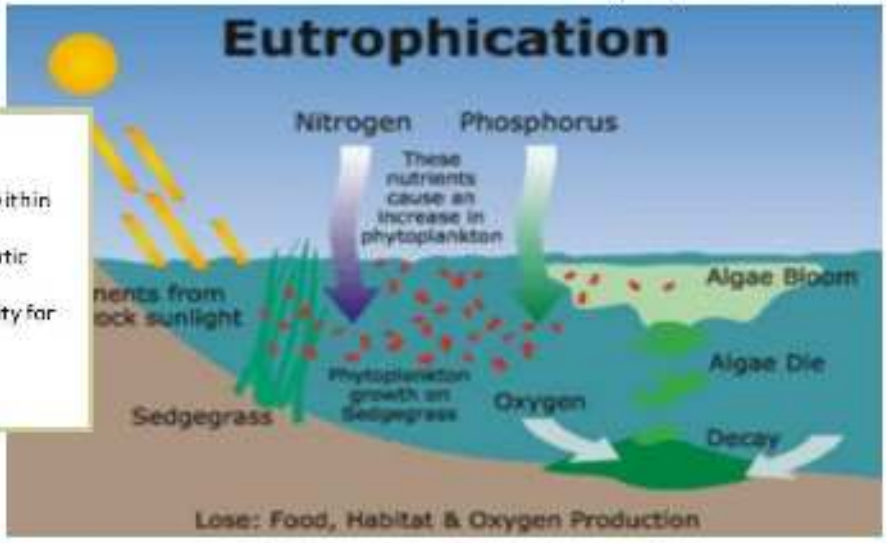


Diagram 3: Phosphorus within the water system causes dangerous, excessive aquatic growth and a decrease in dissolved oxygen availability for aquatic life.

PURIFICATION OF CONTAMINATED WATERS

Vetiver has been experimentally shown to be able to absorb elements and nutrients from wastewater, polluted water, or eutrophicated water.

Eutrophicated Water

Purification of Eutrophicated Water: As soluble N and particularly P are usually considered to be key elements responsible for water eutrophication which normally leads to blue-green algal growth in rivers and lakes, the removal of these elements by Vetiver is a most cost-effective and environmentally friendly method of controlling algal growth.

With intensive farming adjacent to these water bodies, the quantities of N and P are bound to increase. Removal of these elements can be achieved by: (i) planting Vetiver on the edges of the streams or in the shallow parts of the lakes where usually high concentrations of soluble N and P occurred, and (ii) growing Vetiver hydroponically on floating platforms which could be moved to the worse affected parts of the lake or pond. The advantages of the platform method is that Vetiver tops can be harvested easily for stock feed or mulch.

Research in China has shown that the Vetiver system can be used to remove high soluble N and P concentrations in eutrophicated river water (Zheng et al.1997). It was found that Vetiver can reduce soluble P up to 99% after three weeks and 74% of soluble N after five weeks. The authors were of the opinion that the Vetiver system has the potential of removing up to 102 tons of N and 54 tons of P/yr/ha.

From another experiment in China, it was found that Vetiver, which was grown along the edges of the streams, or in the shallow parts of the lakes to first filter off the chemicals, and then grown hydroponically in water along banks, can effectively remove N and P. And, the water became more transparent after treatment (Xia et al.1998; Zheng etal.1998). These Chinese researchers and workers indicated that Vetiver could remove dissolved nutrients, and reduced algal growth within two days under experimental conditions. Thus, Vetiver can be used very effectively to control algal growth in water infested with blue-green algae.

"Vetiver can reduce soluble P up to 99% after three weeks and 74% of soluble N after five weeks."

Picture 10 & 11: Vetiver planting on the edges of the pond. Pacific Adventist University—PNG

Vetiver Pontoons for Wastewater Treatment

Vetiver is highly suitable for the treatment of wastewater due to its extraordinary morphological and physiological attributes and most important of all is its capacity to produce a very high biomass under a wide range of climatic conditions and adverse soil conditions.

The ability of vetiver grass to remove pollutants and water from the growing medium depends solely on its biomass production, hence the faster and higher biomass production the faster and more effective the treatment process is. Therefore, if the biomass production can be estimated for a certain environment, the efficiency of the treatment process can be predicted and subsequently the land area needed can be worked out reasonably accurately

How the Vetiver System Works—PHYTOREMEDIATION

Phytoremediation : The process of removing contamination from soil or water using plants."

PHYTO = Plant
REMEDIATION = Restoring balance

The roots take contaminants from the water into the "body" of the plant. The plant root zone is referred to as the rhizosphere, this is where the action occurs.

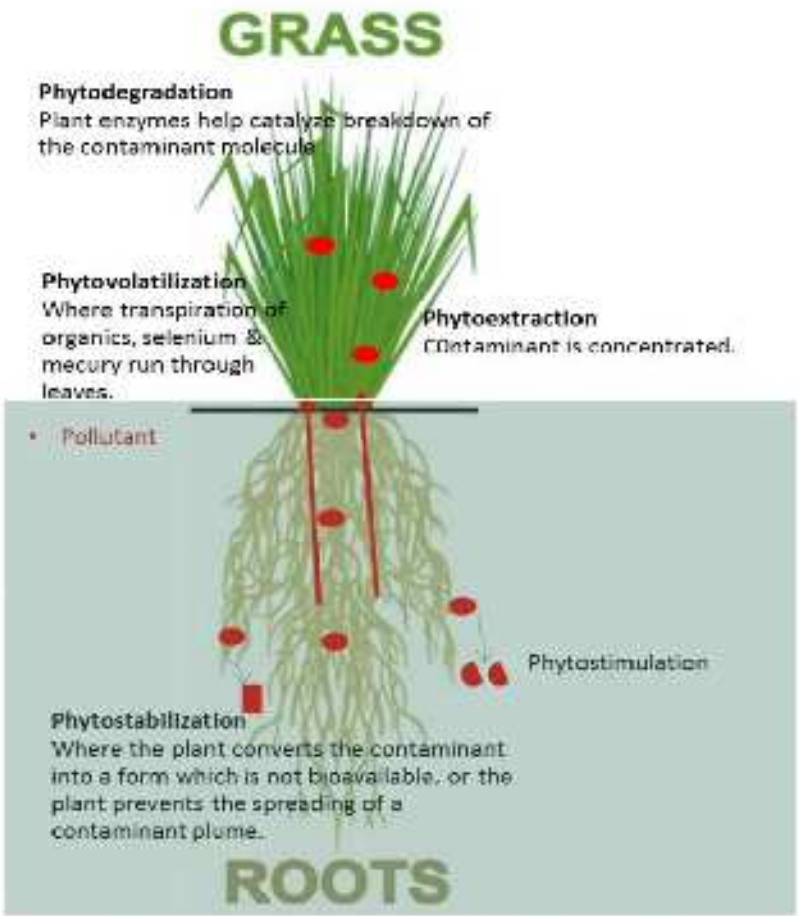
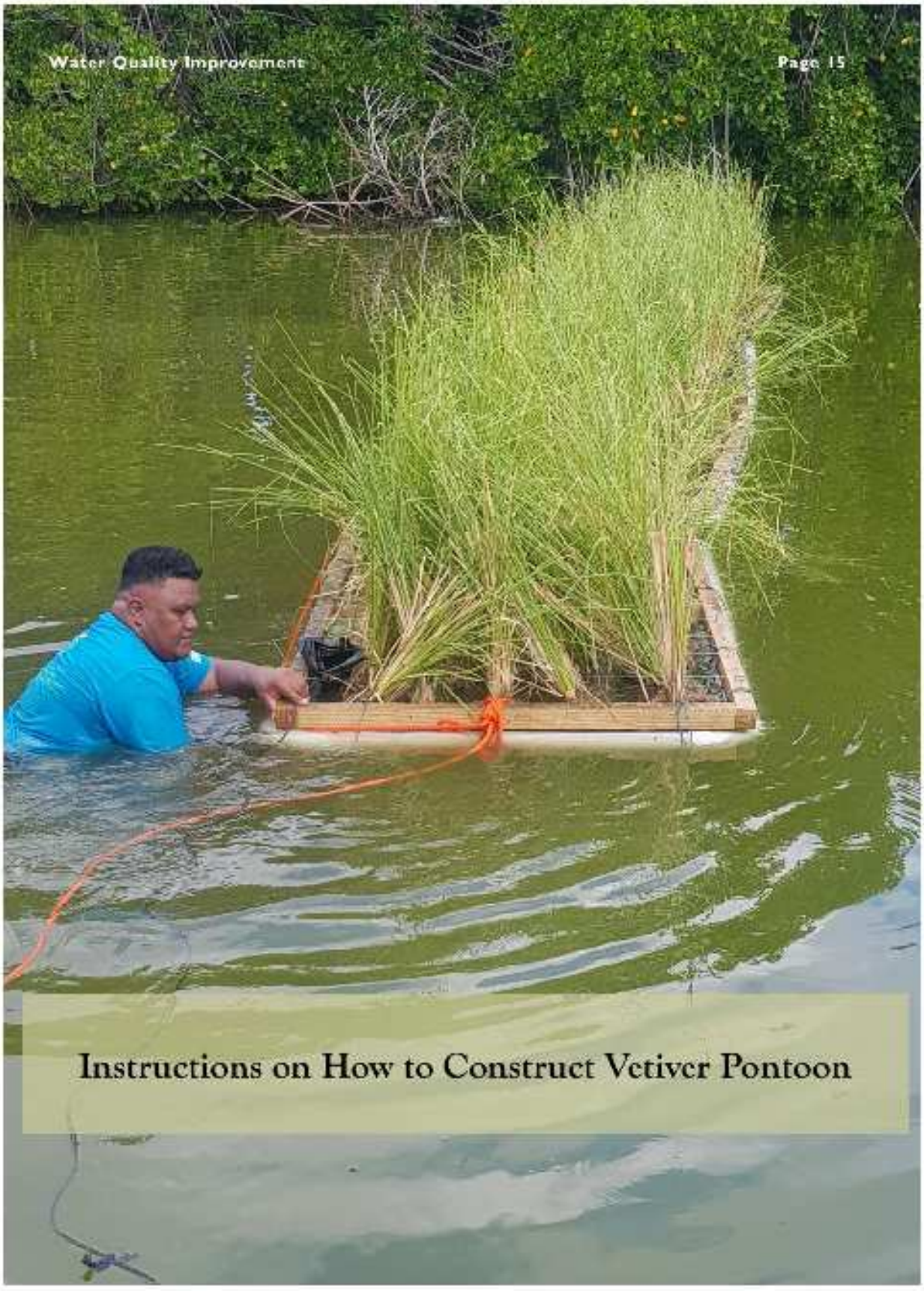


Diagram 4: How the Phytoremediation process works.


Water Quality Improvement
Page 15
Instructions on How to Construct Vetiver Pontoon

Vetiver pontoons (Design)

Plants will be grown hydro-phonically on the platforms (Pontoons) to treat the contaminants in the Tafua pond. There are several ways of constructing the pontoons, however the basic one as used is shown and demonstrated in the following pictures.

Bamboo, soft drink plastic bottles and PVC poly pipes are also used as floaters. No soil media required but for extreme conditions, cocopeat or cocofiber can be used to anchor the Vetiver.

Materials required for the pontoon:

PVC Pipe (100mm)

Equal T Junction (100mm)

90 Degree Elbow (100mm)

PVC Glue

Cable ties (120 pound)

Geogrid (Geosynthetic Matting) or Wire Mesh

- Nails (3 inch and U nail)
- Rope (Nylon)
- Timber (2x2)

Galvanised rust resistant tie wire

Guide on how to Construct Vetiver Pontoon:

1. Measure and cut the PVC pipes as demonstrated.

1. Measure out the PVC pipe to required measurement (1m)

2. Cut the required PVC pipes with electric saw or pipe cutter, all in 1m pieces.

2. **Glue the PVC Pipes and join them together**

1. Apply PVC glue to the end of each PVC fitting.

2. Join the PVC together, ensure to be tightly fitted

3. **Cut and Construct timber frame to fit onto PVC pontoon**

4. Measure out wire mesh to fit timber frame, cut mesh and nail onto the timber frame using 'u' nail.

1. Measure out wire mesh and cut out to measurement of pontoon.

2. Nail wire mesh onto timber frame using 'U' nail, tie the framed timber and wire mesh onto the pontoon.

Tie the framed timber and wire mesh together to the pontoon. Firmly tie with tie wire and or cable tie.

Completed pontoon ready to be launched into the pond.

5. Firmly **join the pontoons together to avoid them from drifting apart.**

6. Remove plastic, place the potted vetiver slips in rows of five, launch and firmly anchor both sides with rope an tie to firm object or tree.

Pictures of the launching of Vetiver Pontoons at the Tafoa Pond during the Education Awareness Campaign (October 2018).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VETIVER SYSTEM TECHNOLOGY
Instructions on How to Plant Vetiver Grass

VETIVER FOR LANDFILL LEACHATE TREATMENT

As part of outputs under the Tuvalu R2R Project (Towards Seaweed Monitoring Survey), the survey team made recommendations for the use of Vetiver Grass to treat wastes before being discharged into the lagoons.

The main sources of nutrient pollution were identified as:

- Leaching from households with pit toilets.
- Leaching of nitrate-rich wastes into ocean from the bottomless septic tanks.
- Pigsties and chicken sheds being cleared into the lagoons.
- Direct input of waste into the coastal area (during times of drought) - open defections.
- Inputs of phosphates from the use of detergents and chemical fertilizers.
- Leaching of leachate from the dumpsite.

The project takes the "ridge to reef" approach highlighting the connectivity of land-use practices at the landfill, residences (bottomless septic's) and the Tafoa pond directly impacting our marine environment.

Why Vetiver for the Funafuti Landfill Site?

Extensive research, development and application have established that Vetiver grass (Chrysopogon zizanioides L.) possesses unique attributes that make it exceptional for environmental protection and rehabilitation.

When applied to landfill projects, Vetiver addresses a multitude of needs:

- Leachate and Wastewater Treatment.
- Slope Stabilization and Erosion Control
- Infrastructure Protection
- Silt Fencing and Sediment Control

When applied to leachate and wastewater, Vetiver acts to:

- Treat and absorb nutrients and pollutants, such as heavy metals.
- Reduce or eliminate the volume of wastewater, and as a form of phytoremediation for contaminated water and land.

How Vetiver Controls Leachate

Vetiver is best suited to leachate disposal due to its high water usage, nutrient absorption rates, and tolerance to elevated levels of nutrients, salt and other toxicities. When applied to landfill leachate, Vetiver acts to:

- Prevent pollution of underlying and surrounding soil
- Prevent the pollution of ground and surface water
- Control the 'bioreactor' by containing and treating surface or underground egresses
- Treat leachate through irrigation methods
- Stabilize dam walls
- Control seepage

Benefits of Vetiver for Landfill onsite treatment

- On-site leachate treatment and disposal
- Multiple methods of application – including seepage control, pontoons,
- irrigation systems and hydroponically
- Low establishment costs
- Fast growth rate
- High water usage
- Low maintenance
- Multifaceted – can address wastewater treatment, leachate disposal,
- infrastructure protection, land rehabilitation, and erosion and sediment control
- Highly tolerant to adverse conditions
- High capacity to remove excess nutrients.

Materials required for Vetiver planting

The quality of planting material

Foremost importantly is the quality of the planting material to be used. Exceptions there, in most cases the preferred planting material used for landfills are 'poly-pots' or 'strips'. They have to be raised in nursery at least 2-3 months in advance. The quality must be checked, i.e. the root development in the pots, the ability of the strips to 'hang together', and the tillers must be matured (3 months and up).

"Vetiver is pest resistant, can recover after fires, and withstands prolonged periods of flooding and drought."

Bare Rooted Vetiver slips

Poly Potted (Nursery bags)

Vetiver Plugs in Nursery Trays

Vetiver Strip

Transporting, handling and storage

It is all about minimizing transplantation stress. As soon as planting material is removed from a nursery (or from an on-farm hedge), the roots are exposed. Hence, the plants have to be kept in the shade and damp (e.g. in buckets of water or in wet soil). During transport they should be shaded. If bare root slips will be used, they must be transported in bags filled with wet newspaper; this is for moisture retention so the roots don't dry out.

If bare root slips are supplied, it is worth considering the option to have it supplied earlier, to keep the slips in water or slurry for 2 weeks (preferably with added rooting hormone, or the locally made juice from water hyacinth), until there is a noticeable new root growth. Soaking can be in the sun. If pots are used, then it is good to 'harden' the plants in the pots, once they showing signs of good growth (that is, reducing the watering frequency in the last 3 weeks before planting).

"Vetiver is best suited to leachate disposal due to its high water usage and nutrient absorption rates."

Key issues to consider

Quality

Freshness, age, and for bare root slips: length of pruning leaves and roots.

Quantity

For slips: the international standard is that these contain at least 2 healthy, viable tillers, but after that counting, considering the local conditions, it may be better to use slips that have 3-5 tillers; this will improve the all-crucial survival rate.

Timing

Supply to site must not too early, to avoid transplantation stress, and obviously for practical reasons of work planning.

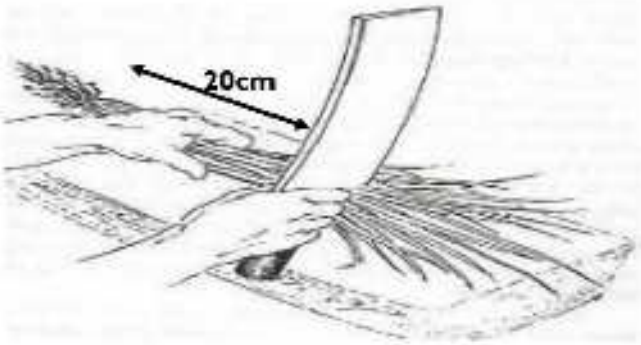
Guide on how to plant Vetiver Grass at landfill site

Planting Procedure

Plant Preparation

1. Cut the roots to 5 cm to prevent them from dying.

2. Trim the grass to 20cm. Trim the top part of the grass off.



3. Divide the clump into planting slips. Slip to have 2-3 tillers. 2-3 tillers is important in hostile areas, if one dies we still have the other or two tillers to grow. In erosion control every growing point is important.

Divide the clump into planting slips. A slip to have 2-3 tillers

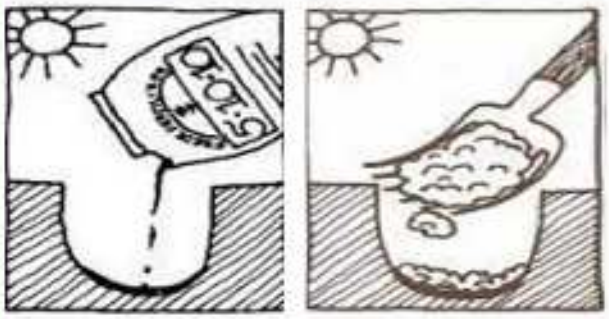
Planting

1. Prepare planting furrow for Vetiver grass planting using spade or digging stick.
Dig furrows deep and wide, in semi-arid areas the furrows depth may exceed 30 cm. This is very important, to ensure that the crown of the plant develops under the soil, that enough water is infiltrating, and to prevent wash-out by heavy rains in early stages.

2. Mix fertilizer at ratio of 2 parts Urea (N) with 1 part Triple Super Phosphate (P).
This is only for one time application during the planting to stimulate vetiver growth.

Nitrogen Potasium

Mix the two fertilizer together at ratio of 2:1



Place a few drops of mixed fertilizer into planting hole

Place Vetiver into hole and cover with soil

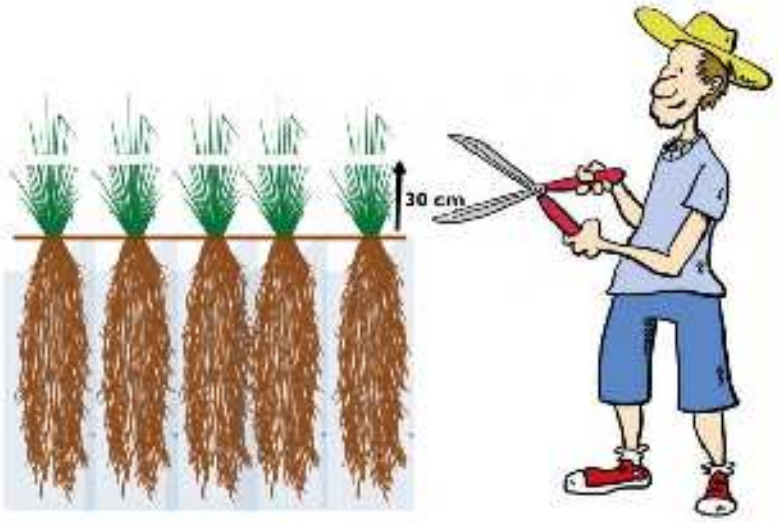
NITROGEN (N) fertilizer works by increasing the plants capacity to produce new tillers.

PHOSPHORUS (P) fertilizer is essential for all living organisms. Plants must have phosphorus for normal growth and maturity

3. Plant each slip into a properly dug terrace on. Spacing between slips to be 10-15cm apart.

4. After planting is done, ensure to water the planting with enough water if there is no rain after planting. If there is rain, watering is not necessary.

5. Trim the leaves after 3 months to encourage tiller growth. Thereafter, trimming can be done 2—3 times a year and the leaves used as mulch, roof thatching or handicraft weaving.



Planting distance

1. For **POLY-POTS** a minimum of 6 pots per meter is required. This is so because they are in their growing stages and have multiplied new slips.

Vetiver in poly-pots (polybags)

Vetiver after polybags were removed.

2. For **STRIPS** the distance is already fixed, which avoids the problem of wrong planting distances.

3. For **BARE ROOT** slips one needs 7-8 slips/ meter, but in semi-arid areas this number may be up to 10 (Vetiver is a social plant, doing better with other Vetiver plants close-by).

Pictures of Vetiver planting at the Funafuti Landfill site during the Education Awareness Campaign (October 2018).

The landfill site before planting of Vetiver grass

Participants ready to clean up the site.

Briefing of participants before site preparation

(Below) Planting of the Vetiver grass by participants and school children.

REFERENCES

Bannasak, A. 2001. Analysis of Lead and Zinc in Vetiver Grass Growing on the Lead and Zinc Mine Tailing using the X-Ray Fluorescence Technique. MS Thesis, Nuclear Technology Dept., Chulalongkorn Univ., Bangkok.

Chomchalow, N. The Role of Vetiver in Controlling Water Quantity and Treating Water Quality: An Overview with Special Reference to Thailand* AUJ.T. 6(3): 145-161 (Jan. 2003)

Truong, P. 2002. The global impact of vetiver grass technology on the environment. Proc. ICV-2, ORDPB, Bangkok, Thailand.

Truong, P.; and Hart, B. 2001. Vetiver System for Wastewater Treatment. Tech. Bull. No. 2001/2, PRVN/ORDPB, Bangkok, Thailand.

Truong, P. Clean Water Shortage, an Imminent Global Crisis. How Vetiver System can Reduce its Impact

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For your environmental problems, we have the solution for you.

The main vision of Eagle Vetiver Systems Limited is to effectively coordinate and implement the Vetiver System Technology for bio-engineering and to promote sustainable environmental protection and waste management (phytoremediation) in Papua New Guinea and the South Pacific Region.
EVS vision also is based on assisting and developing the rural socio-economic sector and provide community initiative participation and ownership. EVS is an associate member of The Vetiver Network International..

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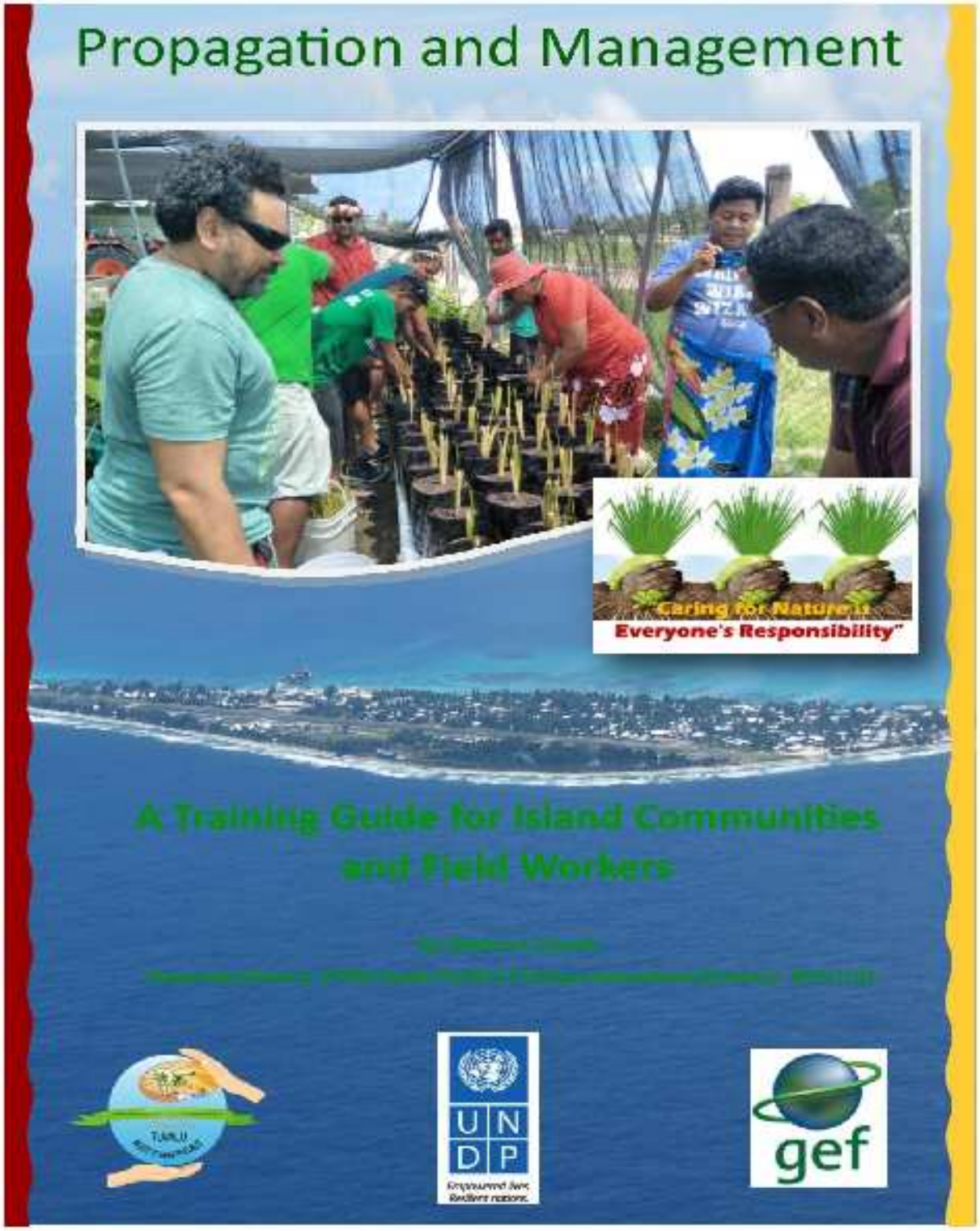
10 ANNEX 3: Training Guide for Propagation and Management



PREFACE

As part of outputs under the Tuvalu R2R Project (Towards Seaweed Monitoring Survey), this guide on best practice propagation and management was developed.

The project funded by (Tuvalu Ridge to Reef Project) TCAP and GEF was implemented over 2 years starting in October 2017 by the Pacific Centre for Environment and Sustainable Development of the University of the South Pacific. The main objective of the project was to empower the local communities to undertake sustainable management decisions in managing wastewater sources, managing seaweed growth and distribution in the lagoons on the atolls. The project takes the "ridge to reef" approach highlighting the connectivity of land-use practices at the landfill, residences (bottomless septic's) and the Tafoa pond directly impacting the marine environment.

Lessons learned from demonstration activities of the project on Funafuti will be documented, and later upscale and applied to the other seven atolls.

ACKNOWLEDGEMENT

I would like to thank Tuvalu Ministry of Foreign Affairs, Trade, Tourism, Environment and Labour for their support in all aspects of our project activities.

Fakafetai lasi to the Tuvalu Ridge to Reef Project who funded the project.

I acknowledge the Ridge to Reef team especially Mataio Tekinene, Ivy S Latasi, Feagaiga Penivao, Lily Nuausala, Lanese Saamu and Elu Tataua.

I also acknowledge the Environment Department for approving our permit to introduce vetiver grass into Tuvalu.

Special acknowledgement to Mr. Viliamu Iese (Research Fellow—Climate Change, Food Security, Disaster Risk Management) and Dr. Antoine De Ramon N Yeurt (Lecturer—Ecosystem Based Adaptation for Climate & Disaster Resilience. Marine Plants Specialist) from the Pacific Centre for Environment & Sustainable Development with The University of the South Pacific.

Finally my special thanks to The Vetiver Network International technical team Sir Richard Grimshaw, Jim Smyle, Dr. Paul Truong, and Dr Dale Reichmeier.

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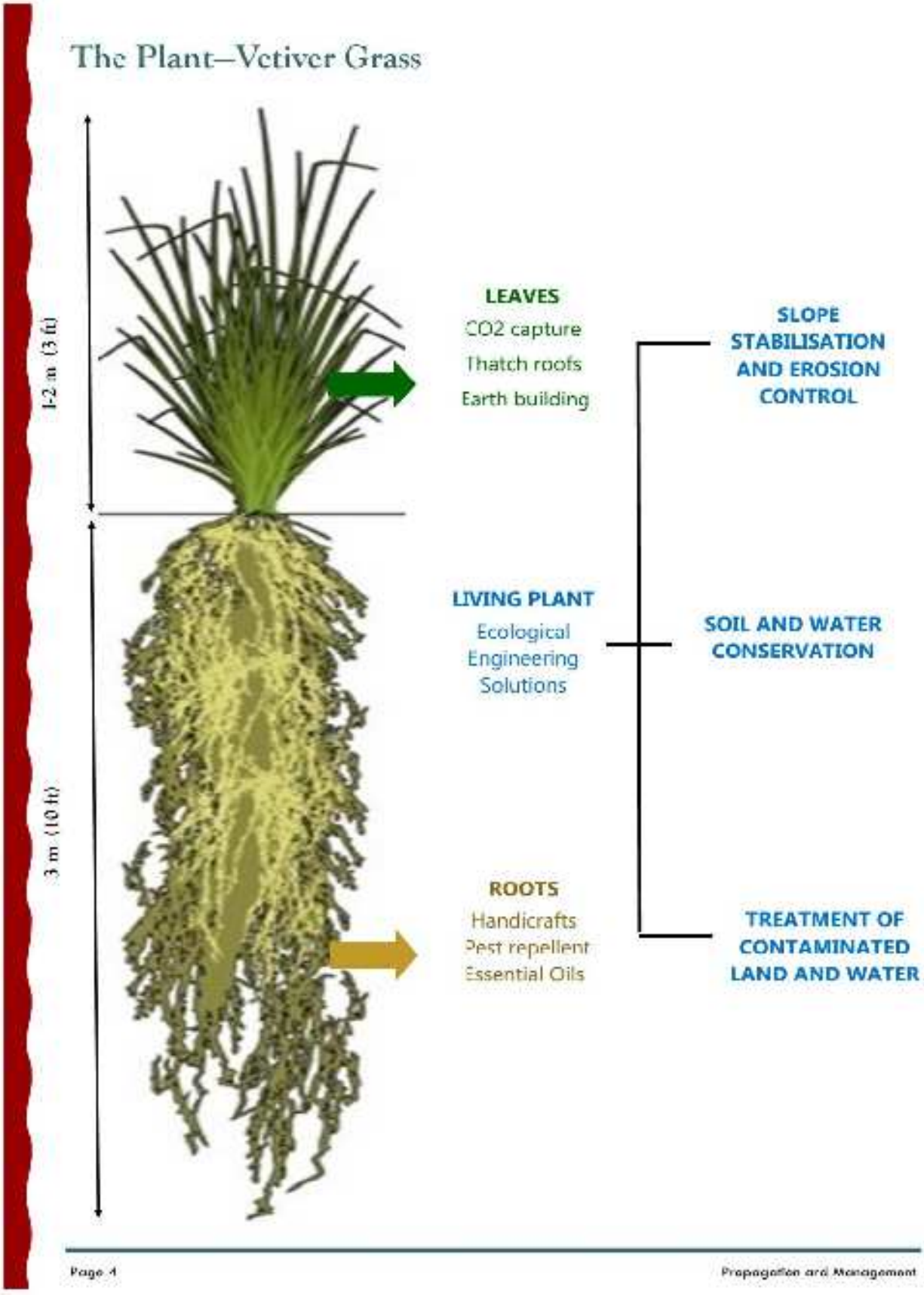

The Plant–Vetiver Grass
1-2 m (3 ft)
3 m (10 ft)
LEAVES
CO2 capture
Thatch roofs
Earth building
LIVING PLANT
Ecological
Engineering
Solutions
ROOTS
Handicrafts
Pest repellent
Essential Oils
SLOPE STABILISATION AND EROSION CONTROL
SOIL AND WATER CONSERVATION
TREATMENT OF CONTAMINATED LAND AND WATER
Page 4
Propagation and Management

Introduction

Since most major applications require a large number of plants, the quality of the planting material is important for the successful application of the Vetiver System. This requires nurseries capable of producing large quantities of high quality, low cost plant materials. The Vetiver Network International promotes the exclusive use of sterile Vetiver species (*Chrysopogon zizanioides*) to avoid it becomes a weed in the new environment. These vetiver species, which is used around the world, originated from the oil producing species in southern India, it is genetically identical to Sunshine in the US or Monto in Australia. Because of its sterility, vetiver grass has to be propagated vegetatively.

2 years old vetiver in PNG

Methods of Propagation

The four common ways to propagate Vetiver are:

1. Splitting mature tillers from Vetiver clump or mother plants, which yields bare root slips for immediate planting or propagating in polybags.
2. Using various parts of a mother Vetiver plant
3. Bud multiplication or in vitro micro propagation for large scale propagation
4. Tissue culture, using a small part of the plant to propagate on a large scale.

Splitting Mature Plants to Produce Bare Root Slips

Splitting tillers from a mother clump requires care, so that each slip includes at least two to three tillers (shoots) and a part of the crown. After separation, the slips should be cut back to 20 cm length. The resulting bare root slips can be dipped in various treatments, including rooting hormones, manure slurry (cow or horse tea), clay mud, or simple shallow water pools, until new roots appear. For faster growth, the slips should be kept in wet and sunny conditions until planting out.

1. Harvesting of Vetiver Clump

2. Splitting of clumps into tillers

3. Planting slips with at least 2-3 tillers

4. Cutting the leaves off at 20cm leave length.

Roots & leaves trimmed

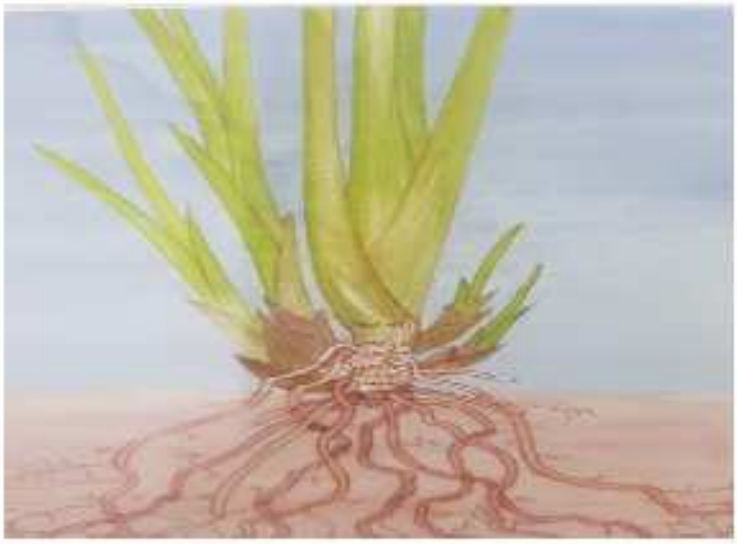
How to measure tiller 15-20 cm

Propagating Vetiver from Plant Parts

Three parts of the Vetiver plant are used for propagation:

Vetiver tillers

- Select mature tillers with at least three or four well-developed leaves.
- Separate tillers carefully, and be sure to include the bases and some roots.



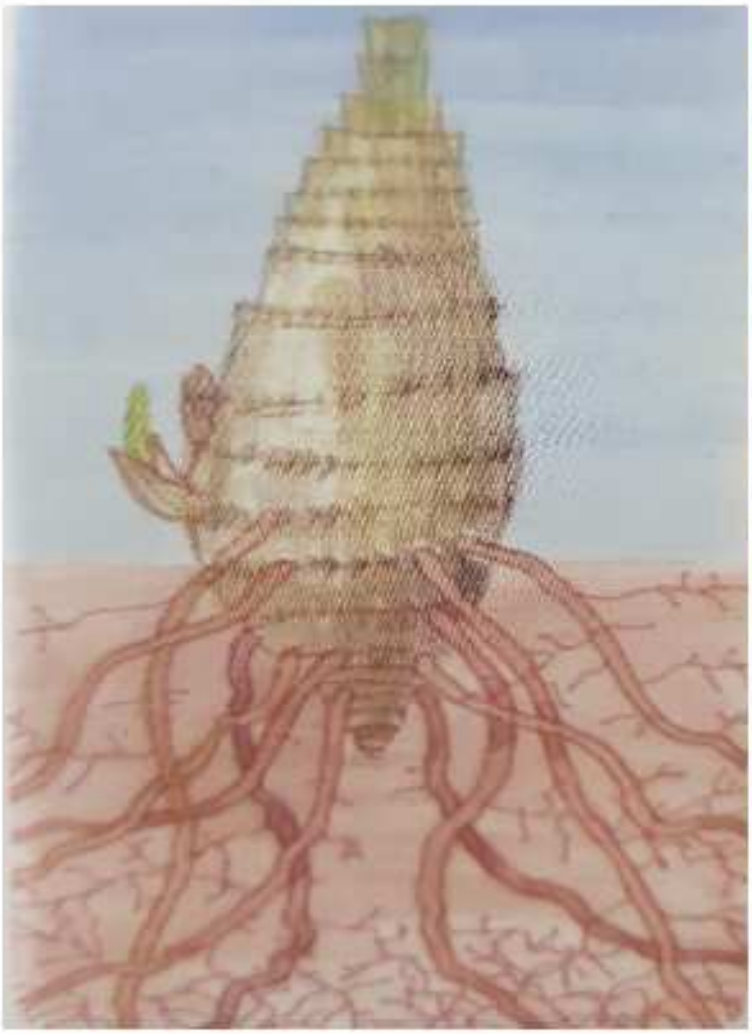
Vetiver culms

A culm is the stem or stalk of a grass. The Vetiver culm is solid, stiff, and hard; it has prominent nodes with lateral buds that can form roots and shoots when exposed to moist conditions. Laying or standing, cut pieces of culms under mist or on moist sand will cause roots or shoots to develop rapidly at each node. Select old culms, which have more mature buds and more nodes than young ones. Cut culms in 30-50mm (1-2") lengths, including 10-20mm (4-8") below the nodes, and strip off the old leaf covers. Expect new shoots to emerge about one week after planting.

Vetiver crown or corms

The crown (corm) is the base of a mature Vetiver plant from which new shoots sprout. Use only the top part of the mature crown. Le Van Du, Agro-Forestry University, Vietnam developed the following four-step method of propagating Vetiver from cuttings: (Du *pers.com.* and Truong *et al.* 2008)

- Preparation of Vetiver cuttings
- Spray the cuttings with a 10% water hyacinth solution
- Use plastic bags to cover the cuttings completely, and leave it alone for 24 hours, and
- Dip clay mud, asprin or manure slurry, and plant in a good bed.



Preparing Water Hyacinth Solution

Water Hyacinth solution contains many hormones and growth regulators, including gibberellic acid and many Indol-Acetic compounds (IAA). To prepare rooting hormone from Water Hyacinth:

- Remove Water Hyacinth plants from lakes or canals
- Put plants into 20 litre-plastic bag, and tie it closed
- Leave the bag for about one month until the plant material has decomposed
- Discard the solid parts and keep only the solution
- Strain the solution and maintain in a cool place until use.

Propagation and Management Page 7

Spraying cuttings with 10% water hyacinth solution (left) and cover cuttings completely with plastic bags, and leave them for 24 hours

Advantages/Disadvantages of using bare root slips and culm slips

Advantages

- Efficient, economic, and a quick way to prepare the planting material
- Small volume results in lower transportation cost
- Easy to plant by hand
- Large numbers can be mechanically planted in large areas.

Disadvantages

- Vulnerable to drying and extreme temperatures
- Limited on-site storage time
- Requires planting in moist soil
- Needs frequent irrigation in the first few weeks
- Recommended for good nursery sites with easy access to irrigation.

Planting Strips

Planting strips are a modified form of polybags. Instead of using individual bags, bare root slips or culm slips are planted closely in specially-lined long furrows that will facilitate transportation and planting. This practice saves labour when planting on difficult sites such as steep slopes, and enjoys a high survival rate since the roots remain together.

Preparation and Planting of Vetiver Grass in strips in Funafuti—Tuvalu Atolls by the SIR team

Polybags or stock cube (nursery trays)

Plantlets and bare root slips are planted in small pots or small plastic bags containing half soil and half potting mix and maintained in the containers for three to six weeks, depending on the temperature. When at least three new tillers (shoots) appear, the plantlets are ready to be planted.

Advantages/Disadvantages of planting in polybags & Strips

Advantages:

- Plants are hardy and unaffected by exposure to high temperature and low moisture
- Lower irrigation frequency after planting
- Faster establishment and growth after planting
- Can remain on site for longer before being planted
- Recommended for harsh and hostile conditions.

Disadvantages:

- More expensive to produce
- Preparation requires a longer period to prepare, four to five weeks or longer
- Transporting large volume and increased weight is expensive
- Increased maintenance cost following delivery, if not planted within a week.

Planting strips (left) in containers and removed from containers (middle) and ready to be planted (right).

VETIVER NURSERY

Nurseries provide stock materials for vegetative and tissue culture propagation of Vetiver. Establishment of a nursery is very important to supply adequate and quality plant material. The following are criteria will facilitate the establishment of productive, easily managed Vetiver nurseries:

The Vetiver Kid in front of his family nursery in Lae—Papua New Guinea

Soil Type

Sandy loam nursery beds ensure easy harvesting and minimal damage to plant crowns and roots. Although clay loam is acceptable, heavy clay is not.

Nursery on sandy loam soil near river bank in Kimbe—PNG

Topography

Slightly sloping land avoids water-logging in case of over watering. Flat site is acceptable, but watering must be monitored to avoid water-logging, which will stunt the growth of young plantlets. Mature Vetiver, however, thrives under water-logged conditions.

Nursery on a slightly sloping land in Kimbe—Papua New Guinea

Nursery Upkeep

General upkeep of the nursery is very important to ensure quality vetiver slips are produced. Supply of quality slips is also very important for success for any projects.

Trimming of vetiver to encourage tiller growth—Lae

Well trimmed nursery in Lae—Papua New Guinea

Propagating vetiver slips in nursery trays

Well managed nursery in polybags—Africa

Weed Control

Weed control in establishment and early growth phases is essential. As vetiver is extremely intolerant to Glyphosate weed killer (RoundUp), it must be done manually.

Very bad weed infestation (above) and manual weeding - Vietnam

11 Annex 4: Vetiver Latrine Guide (Eco-friendly toilets)

Vetiver Latrine Guide

A "how to" guide to successfully install a natural, sustainable latrine using vetiver grass

The use of vetiver grass (*Chrysopogon zizanioides*) replaces the need for a concrete block lined pit, creates privacy and actively helps decompose the waste. Jiji grass (*Achnatherum splendens*) can be used as an alternative in colder or harsh conditions where vetiver does not grow. Banana and papaya can be planted around the grass hedgerow to enjoy a healthy fruit harvest. Vetiver grass can be harvested and used for many purposes.

The most up-to-date version of this guide, in multiple translations, can be found at:
http://www.healthy-mind-body.com/humanitarian/vetiver_latrine.html

1

Benefits:

- Less expensive than traditional latrines ($25-50 instead of $500 for materials to make the basic latrine).
- Easily upgraded so that an elevated toilet, ventilation and a privacy shelter can be added if desired.
- Less materials needed making installation in remote regions possible.
- Vetiver roots reinforce pit walls effectively. No need for concrete block lined pit.
- Banana and papayas can be added to convert the waste into food.
- Greywater (waste water from kitchen, bath and laundry) can be used to water vetiver and bananas.
- Easily moveable concrete slab allows for reuse of materials after latrine pit is full.
- Vetiver provides a privacy screen, but can be cut regularly and has multiple uses (fuel, animal feed, compost, crafts, thatch roofing, earth wall construction, etc).
- Vetiver roots actively help decomposition of the waste and reduce pollutants leaking from the pit.
- Easy to build, so that all in need can master the process and make latrines for themselves.
- Self cleaning and repairing, the slope of the slab allows rainwater to wash into the pit and clean the latrine and if the grass is damaged, it will grow back spontaneously.

Cons:

- Vetiver grass has some minimal needs that must met: 1) watering if planted in the dry season; 2) at least a partially sunny location; 3) protection from grazing animals (until plants are established).
- Vetiver grass takes 1-2 growing seasons to reach full size, to enjoy the benefits of the privacy screen.
- Local sanitation laws may prohibit the use of a vetiver latrine.

	
Vetiver prevents erosion even in severe conditions. This image shows a vetiver hedge holding a wall of soil in place despite the fact that the soil around it, without established grass, completely washed away.	Vetiver roots are massive, up to 4-5 meters deep. This image shows a clump of vetiver (leaves and stems have been cut back) after being dug up by three men using hand held hoes aided by a wood tripod to help lever the clump out of the ground.

Pit Location

Four factors are important to consider when determining the best location for the vetiver latrine.

1. Sun: Vetiver loves sun and at a minimum needs partial sun exposure throughout the day. If an area has dense overgrowth, then it is best to prune back some of the surrounding trees and shrubs.

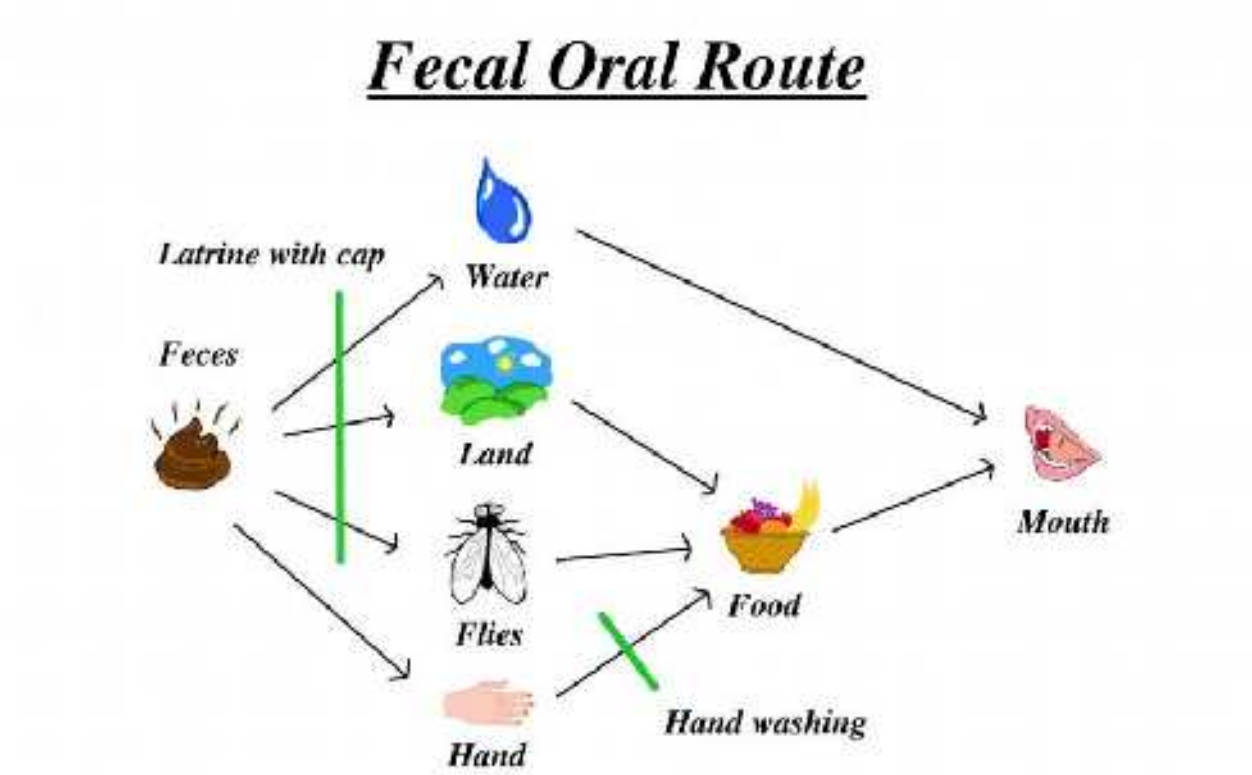
2. Contamination: It is important that the contents of the latrine pit stay safely in the pit. Simple precautions can be taken to prevent any effluent leaking from the pit (leachate) from contaminating drinking water or local waterways. The pit should be located downhill from water sources whenever possible, especially sources of drinking water such as springs and wells. Even then, the pit should be 30 meters from water sources. The pit should be about 2 meters above the groundwater table and above flood level during the wet season. In some cases, the features of the site maybe more important than the distance.

3. Convenience: The latrine should be close to the family's dwelling, so that a sick person can reach it in the middle of the night, but far enough away so that latrine odors cannot reach the house. Placing the latrine within 6 meters of any home, is a good rule of thumb.

4. Level Surface: Although the pit can be located on sloped ground, the concrete slab once in place needs to be level.

Sanitation

Some diseases are caused by germs that live in feces and can only spread by the fecal oral route. The common ways a disease can spread from feces to the mouth are contamination of: water, land, flies, hands and food. The combination of the use of clean water, a well-built latrine and hand washing completely blocks these routes of infection and promotes health.



Construction

The Pit:

Dig the pit in stable ground and make the sides directly vertical (as opposed to a funnel shape) to minimize the risk of pit collapse. The shape, width and depth of the pit can vary. The table below outlines important factors to consider when choosing the pit shape. For example, if minimizing expenses is a priority or if the slab needs to be transported short distances (100m or so), then a round pit will be a better choice. It uses less materials and can be rolled to its final location. However if the slab is made on-site and there is enough money for a larger, longer lifespan pit, then a square pit may be the right choice. Some cultures prefer privacy shelters that are either round or square. Choose a pit shape to match the shelter shape. Whichever shape is chosen, make sure the concrete slab matches the pit shape as well. For example, a round pit will have a round slab and a square pit a square slab. This

way when the vetiver is planted next to the slab, the roots will be close to the vertical pit walls and capable of reinforcing them.

Round	Square
Pros: 1) A round pit has stronger walls 2) Less materials are needed for the concrete slab 3) It is easier to move the slab, as it can be rolled	**Pros:** 1) The pit lifespan is longer because a square pit has a greater volume than a round one 2) The concrete slab is easier to make
Cons: 1) The concrete slab is a little more difficult to make 2) A round pit has less volume than a square one, making the lifespan shorter	**Cons:** 1) The concrete slab is harder to move, it weighs about 200kg 2) More materials are needed and hence it is more expensive 3) Square pit walls are not as strong

The width and depth of the pit can be modified. The final volume of the pit will determine its lifespan. A square pit that is 1 meter wide and 2.3 meters deep, as shown in these designs, will serve a family of six for five years. This calculation accounts for the top ½ meter of the pit being filled with earth when it is retired. This is done to avoid contamination of the surface soil. To determine the lifespan of a pit expect a volume of at least 0.06 cubic meters per person per year. A greater volume, such as 0.1 cubic meters, should be expected if anal cleansing materials such as corn cobs or stones are used. This calculation is based on a conventional latrine. A vetiver latrine may last longer because the waste is at least partially decomposed by the vetiver roots. Experience has shown that a pit less than 1.2 meters deep will last only about a year.

Calculation of Pit Size: Example
Expected Usage: 6 people x 0.06 cubic meters x 5 years = 1.8 cubic meters
Usable Pit Size: 1 meter x 1 meter x 1.8 meters (2.3 m – 0.5 m to fill top) = 1.8 cubic meters

If the width of the pit is altered, modify the size of the concrete slab and beams accordingly. The slab should be 20 cm wider than the pit and the concrete beams 70 cm wider than the pit.

The Slab:

A strong concrete slab can he made from the following standard mix: 3 parts sand, 3 parts gravel and 1 part cement. If the slab is made on-site in a remote location, the sand and gravel can be sourced locally. The gravel should be "thumb sized" or smaller. The sand should be free of dirt and debris. A simple mesh screen placed over a bucket can he used to separate the sand from any debris and water can be used to remove any dirt. The ratio of sand, gravel and cement can be modified slightly depending on the availability of local resources. For example: 2 parts sand, 4 parts gravel and 1 part

cement will work. Alternatively: 4 parts sand, 2 parts gravel and 1 part cement will also work. Add water to the mix until the concrete is workable. Plan on at least 3 buckets of water for the mix and for cleaning tools.

The slab and beams can be shaped by using wood forms placed on level ground or by digging a depression into level ground. In either case, reinforce the concrete with 3/8" rebar (9.5 mm) as shown in the design. Once complete the rebar should be embedded inside the slab and beams, so no metal is protruding out of the concrete. Before pouring the concrete, small stones can be used to elevate the rebar so that it is in the proper location. A wood cut form is the best template for the hole in the center of the slab. It can be made in a keyhole shape, as per the specifications shown in the designs later in this guide. A bucket can also be used to create the hole. This hole should be no larger than 25 cm in diameter, so that a small child will feel safe using the latrine. Remove the template when the slab starts to harden (about 3 hours) and then cover with damp cloths, cement bags, hay, sand or a sheet of plastic to allow the concrete to dry slowly. Although some masons use concrete within 6 days of pouring it, a curing time of 21 days will insure a strong slab. Once cured, move the slab to cover the pit. Placing large stones under edges of the slab around the top of the pit, will help reduce the risk of pit collapse.

If a seat is desired, this can be constructed with cement blocks, bricks or wood. Be sure the hole is covered to prevent flies from accessing the pit. A square cap template can easily be made from wood to cast a concrete cap. Alternatively wood can be used to make the cap, but will not last as long as a concrete one. It is best to make the cap without a handle to encourage the use of the foot to slide it on and off the hole. This helps prevent hand contamination.

Rot-resistant wood or bamboo can be used as an alternative to a concrete slab. The wood should be shaped similarly to the slab and covered with mud and cement mortar. These materials are less expensive, but will have a shorter lifespan than a concrete slab. It is unlikely they can be reused for future latrine pits.

Slab Tools List – Reusable items
4 – wood 5 cm X 10 cm (2X4's), each 1.2 meters long, for forms to cast the **square concrete slab**
1 – thin 6.3 cm (2.5") band fiberglass lawn edging, 377 cm long, to cast the **round concrete slab**
3 – wood 5 cm X 10 cm (2X4's), each 1.8 meters long, used for forms to cast support beams
4 – wood 5 cm X 10 cm (2X4's), for 40 cm X 30 cm template to cast **the square concrete cap**
1 – thin 6.3 cm (2.5") band fiberglass lawn edging, 125 cm long to cast the **round concrete cap**
1 – wood block cut to the shape of a keyhole as form for the slab hole. If not available a small bucket about 25cm in diameter can be used as a form.
Trowel and shovel for handling cement
Cleaning supplies, including ground sheet to prevent cement from being contaminated with dirt
Saw or bolt cutters capable of cutting rebar
Short handled hoe, shovel and digging bar
Fasteners to build the wood forms (nails and hammers or wood screws and screwdriver)

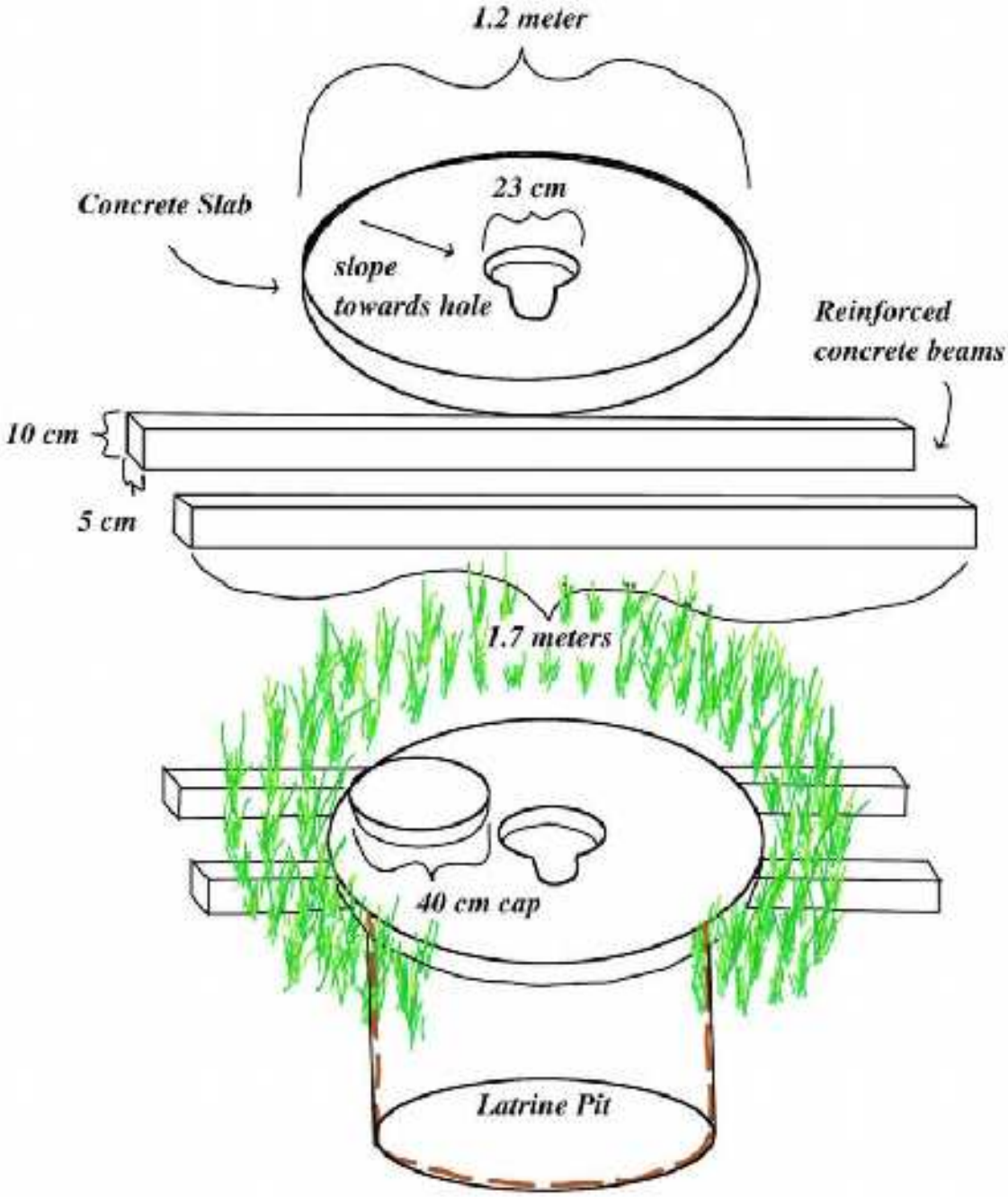
Materials List – One time use items
50 – Vetiver slips (small plants)
2 – 9.5 mm (3/8") rebar 6 meters long
1 – 50kg bag cement
3 – 3 gallon buckets water (for cement mix and cleaning)
3 – buckets sand
3 – buckets gravel

Latrine pit with nice straight walls

Use feet not hands to move cap

Slab being cast using bucket and wood forms. This bucket is too big, about 30 cm instead of 25 cm.

Vetiver Latrine Design



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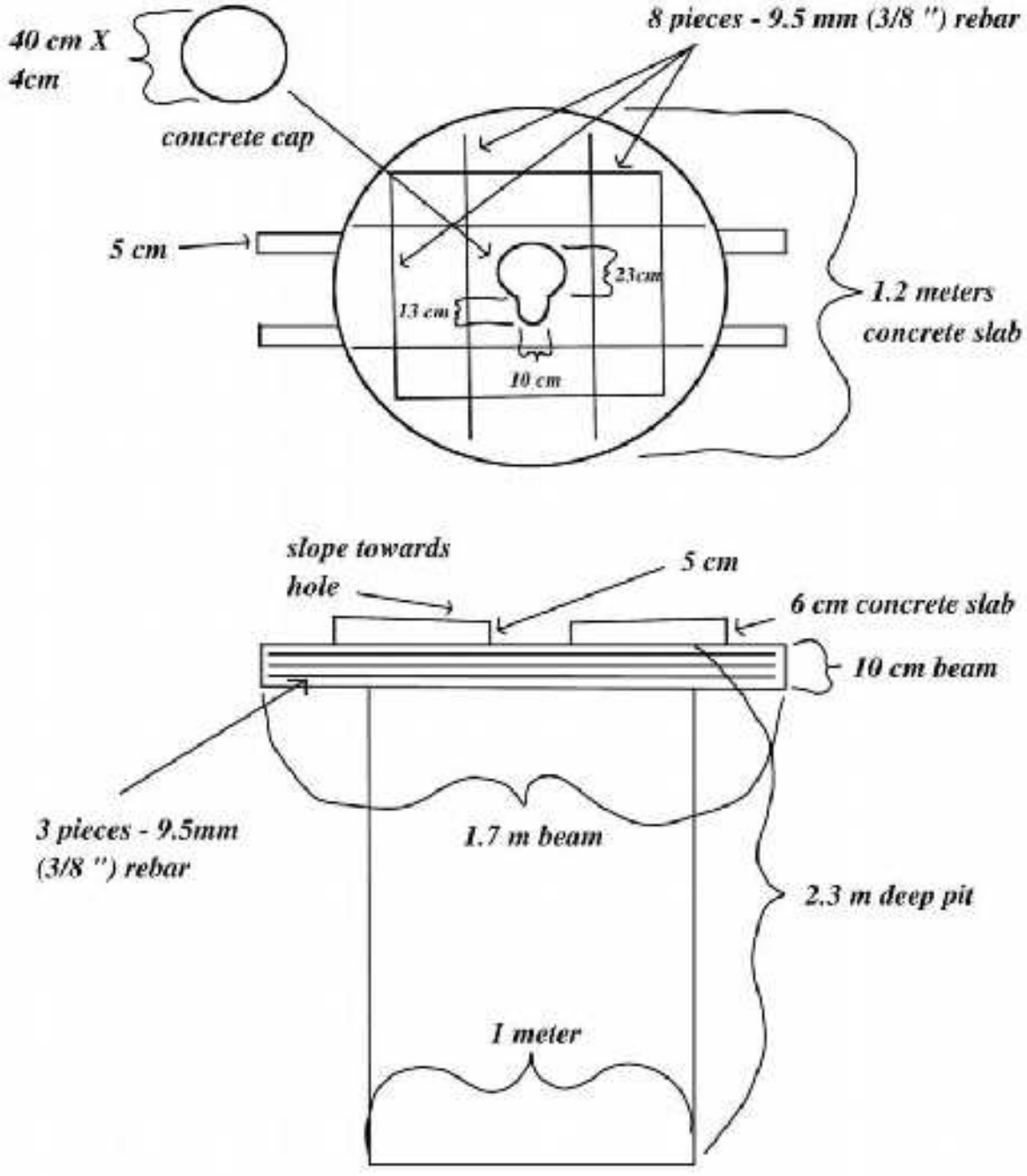
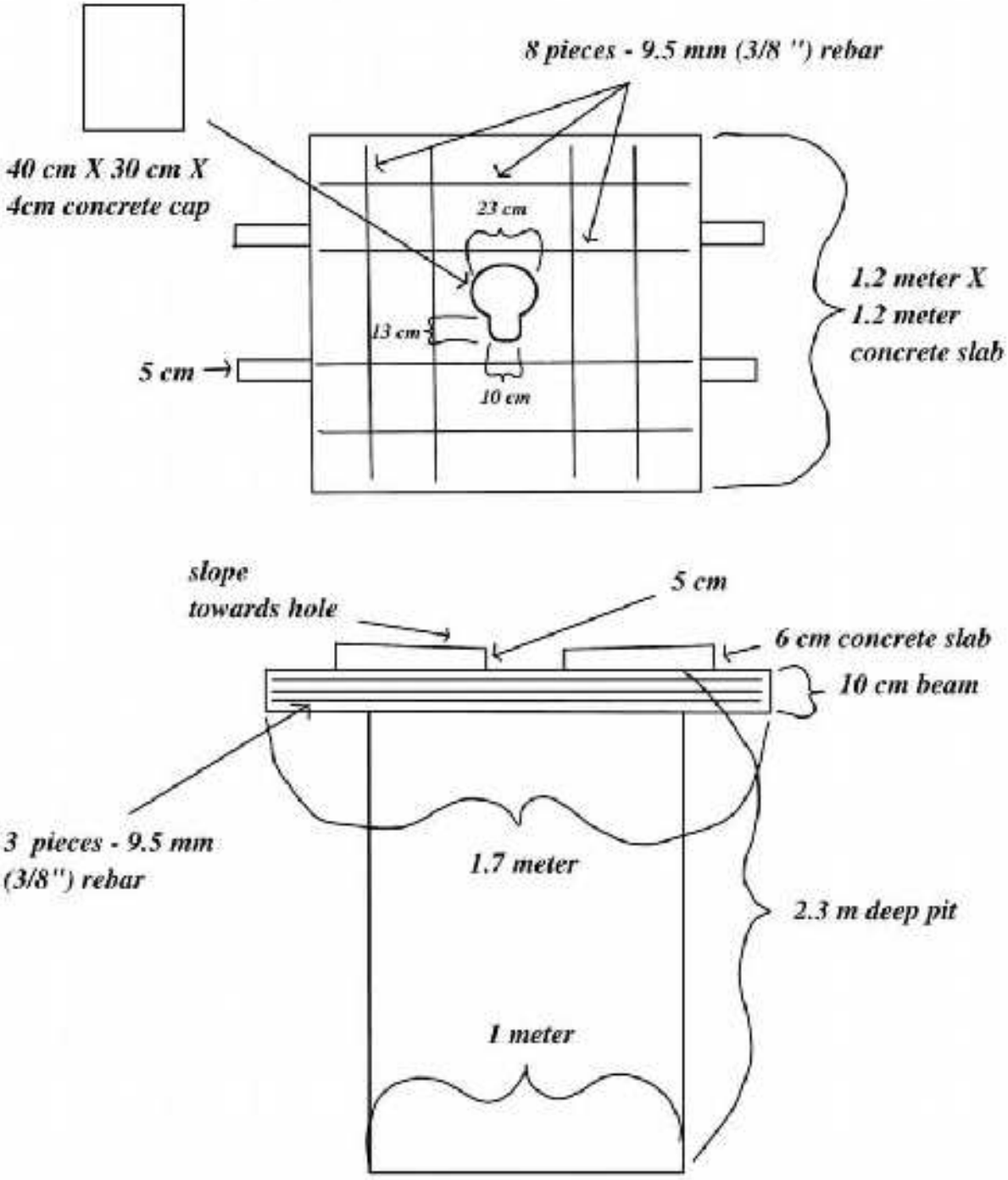
Round Vetiver Latrine



Square Vetiver Latrine



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Vetiver Planting

Plant the vetiver slips at 10-15 cm spacing (about the width of your fist) in three separate rows around the latrine with 30-40 cm between the rows. Leave an opening on one side for an entrance to the concrete slab. The row of vetiver plants closest to the latrine, must be within 30 cm of the pit wall (10 cm from the edge of the concrete slab) so that roots can easily reach the pit wall. Vetiver roots develop downwards vertically, not horizontally. Plan on purchasing about 50 vetiver slips when making a latrine the size depicted in the designs here. It is best to plant the grass in the rainy season as they will not require manual watering as they develop. If it is planted shortly before dry season, water the grass every four to five days if there is a lull in the rain until new shoots at the base of the plant are growing well. Greywater (from laundry, kitchen and bath) can be used to water the plants. They may look dry and gray the first few months after planting but keep watering them and know that they are just concentrating their energy to form roots. Cover the bare soil with organic matter or mulch. The vetiver grass can be cut to provide mulch as it grows. Leaves, wood chips, other grass clippings, plant prunings and even cardboard or paper can be used to cover the soil. This is important as it prevents weeds and helps the soil retain moisture. While the vetiver is developing it should be protected from grazing animals. Goats can eat the grass down to the ground if given a chance, but if the plants are already established (more than 4-6 months old) then they will spring back easily within a few weeks of being eaten.

Vetiver latrine with newly planted slips, notice that the slips are planted right next to the slab and will not interfere with the slab as the roots grow down vertically and not horizontally.

Vetiver Care

Over the first year, the vetiver will grow together to form a solid hedgerow. The hedgerow will remain as such for several decades and the three rows will ultimately look like a solid planting after a few years. It should be cut back annually at the end of the dry season to promote new growth. It can be cut more often (3 times a year) and will grow back more vigorously each time. When pruning, leave about 30 cm of grass at the base. The grass clippings can be used for many purposes. They make excellent animal feed when freshly cut and can be composted. They can be pressed into bricks manually with a Byrant Press and used as a clean, smokeless fuel. It can also be used for handicrafts, thatch roofs and to reinforce earthen walls. After the first growing season, the plants will flower sending up very stiff flower stems that can be 1-2 meters tall. These can be cut and serve as reeds to provide a stiff backing for crafts such as woven mats.

Latrine Care

It is important to keep the concrete slab clean on a regular basis using soap and water. Do not use chlorine or bleach products to clean the latrine. This is harmful to the roots of the vetiver and can arrest its natural cleaning process. If a shelter is not constructed over the slab, then rain will help the cleaning process because the water will naturally run down the slope of the concrete slab into the pit.

Maintenance is important to prevent the rare possibility of pit collapse. In Haiti, of 365 vetiver latrines installed during a rural project, only 2 (0.5%) of the pits had collapsed during a survey performed 2.5 years later. ***The single most important measure that can be taken to prevent pit collapse, beyond locating it in stable ground, is to cultivate a healthy vetiver hedgerow.*** The second most important measure is to watch for early signs of unstable ground. Normally signs of pit failure will show long before collapse and with proper maintenance the process can be halted. If the latrine pit shows signs of collapse, such as a hole forming near the slab's edge, fill the hole with wood, then cover with earth and plant vetiver on top. The vetiver roots will stabilize the hole and prevent further collapse. Alternatively, large rocks can be used to prop up an unstable slab. If the collar of the pit has opened to the point where it cannot be repaired, then a new pit should be dug and the vetiver and slab transferred over.

Latrine with mature vetiver privacy screen

Latrine with ventilation pipe and elevated seat

Reuse:

When the latrine pit is full, the concrete slab and vetiver grass can be moved to the new pit location. Dig down along the side of a vetiver clump about 30 cm. Then cut horizontally and pull the clump out of the ground. Do not worry about the roots being cut. New roots will begin to form from the root crown (the woody heart of the clump just below the surface of the ground). The clump should have about 15 cm of roots intact as well as the crown. Trim the leaves to a height of 15-20 cm and divide it into slips containing about 3-5 individual slips using a machete, hoe or axe. Replant these as they were planted when latrine was first built. The old pit should be covered by ½ meter of earth. In two years this space can be gardened or alternatively a fruit tree can be planted immediately.

Vetiver slips planted in row

Vetiver slips with root crown at the base

Modifications

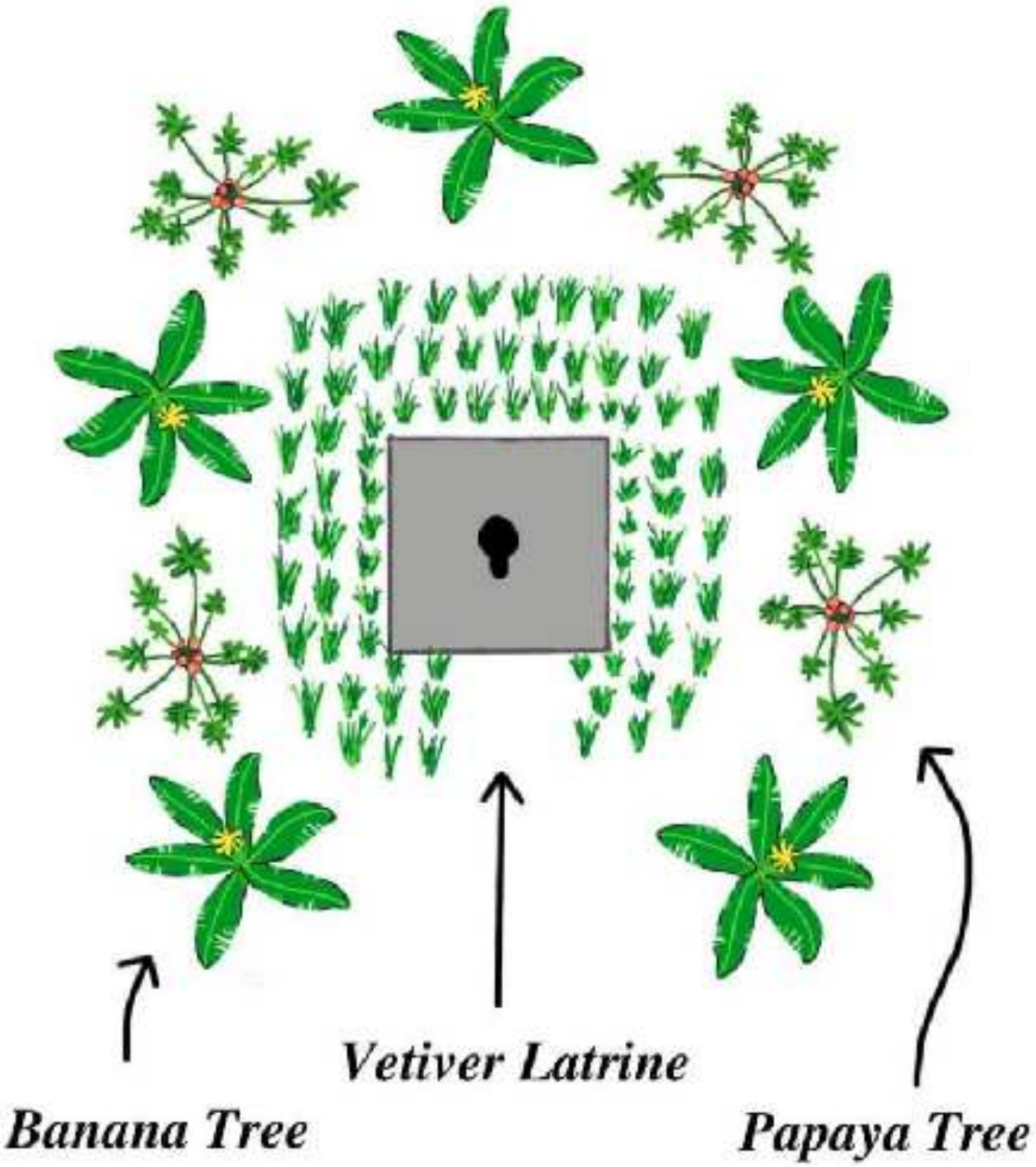
Upgrades:

The basic vetiver latrine shown in this tutorial is easily upgraded. Adaptations may be important for the latrine to be accepted in different cultures depending on the local norms. A shelter can be built on the concrete slab for more privacy. Also, an elevated toilet seat can be constructed directly above the hole in the concrete slab. A 4-inch diameter ventilation pipe (PVC pipe is an ideal material) can be cast into the concrete slab. If there is a shelter, the pipe extends ½ meter above the peak of the roof to carry odors away. It is important to place a screen or mesh over the pipe to prevent insects from accessing the pit. An excellent "how to guide" for the design and construction of privacy shelters, fitting for varies cultures and budgets, can be found at: http://www.clean-water-for-laymen.com/privy-privacy-shelter.html.

Banana Circle:

Another important modification is the addition of a banana circle around the basic vetiver latrine. Communities are more likely to accept and care for the vetiver latrine if there are fruiting trees providing immediate, tangible benefit. Plant five banana trees, evenly spaced, just beyond the vetiver hedgerow. Papaya trees can be planted between each pair of banana trees, but leave one space open to access the latrine. Greywater can be used to water the banana circle as well as the vetiver during dry season, until the plants are established. Although it is safe to eat fruits from these trees, low growing fruits and vegetables should not be grown near the latrine due to risk of human waste contamination.

Vetiver Latrine With Banana Circle



Papaya Seed Antiparasitic Treatment:

Intestinal parasites are more common the generally believed, even in first world countries. In addition to causing stomach symptoms and weight loss, they can also affect an individual's mental concentration and emotions. If papaya trees are grown around the latrine, or the fruits are available locally, the seeds can be used as a powerful antiparastic. One study found papaya seeds (*Carica papaya*) to have medicinal properties effective against intestinal parasites, and with minimal to no side effects[1].

They are given as a one time dose orally. The seeds can be swallowed fresh, or dried and crushed. Take 4 teaspoons of fresh seeds once or 2 teaspoons (4gm) of dried seed once. The dose is the same for adults and children. The seeds have a peppery flavor that may not be desirable to some. For those who can swallow them without chewing, the fresh seeds may be the easiest way to take the treatment. For children, or those who cannot swallow them whole, then the dried, crushed seed can be mixed with a sweetener such as honey, cane syrup or peanut butter. Peanut butter masks the flavor and texture the best. This treatment can be safely consumed on a monthly basis to prevent and treat stomach worms. It should not be taken in higher or more frequent doses. At high doses papaya seeds are known to temporarily cause infertility. In regions where papaya grows naturally and meals are served to school children, a periodic school treatment program could be instituted to improve the health and performance of its students at a minimal expense.

A papaya this size yields about 3 antiparastic treatments (12 tsp of fresh seeds or 6 tsp of dried seed)

References:

1. Okeniyi J, Ogunlesi T, Oyelami O, Adeyemi L; 2007; Effectiveness of dried Carica papaya seeds against human intestinal parasitosis; Journal of Medicinal Food; 10(1): 194-196.

Credits:

1) Owen Lee (www.vetiverlatrine.org); Creator of the basic vetiver latrine, guide editor and owner some of the vetiver latrine photos.

2) TVNI (The Vetiver Network International, www.vetiver.com); Owner of the vetiver and jiji grass photos.

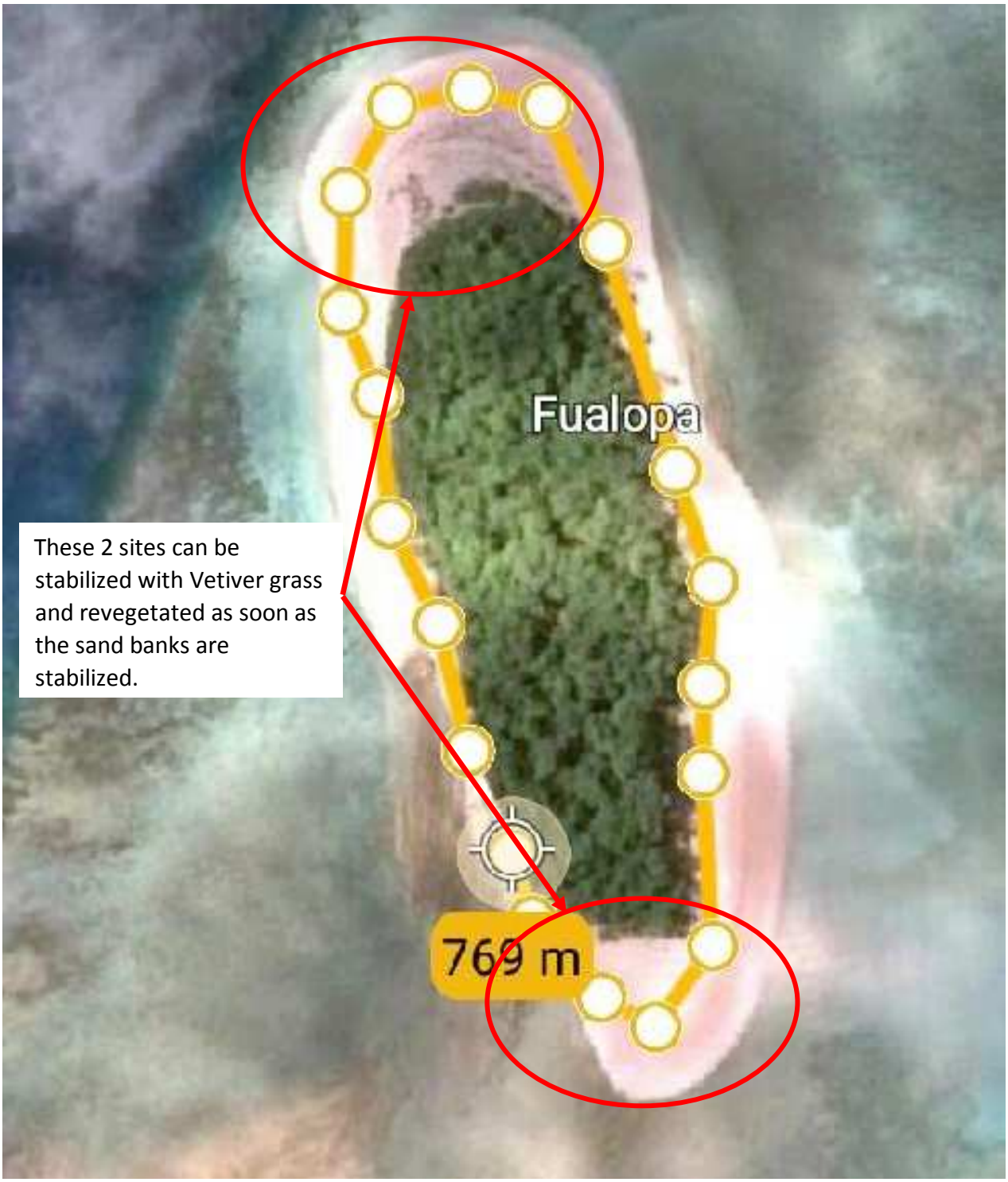
3) Dale Rachmeler, PhD (drachmeler@mac.com); Guide editor.

4) Roger Gietzen, MD (www.healthy-mind-body.com & roger@healthy-mind-body.com); Guide creator, illustrator, inspiration for many of the vetiver modifications and owner of some of the vetiver latrine photos.

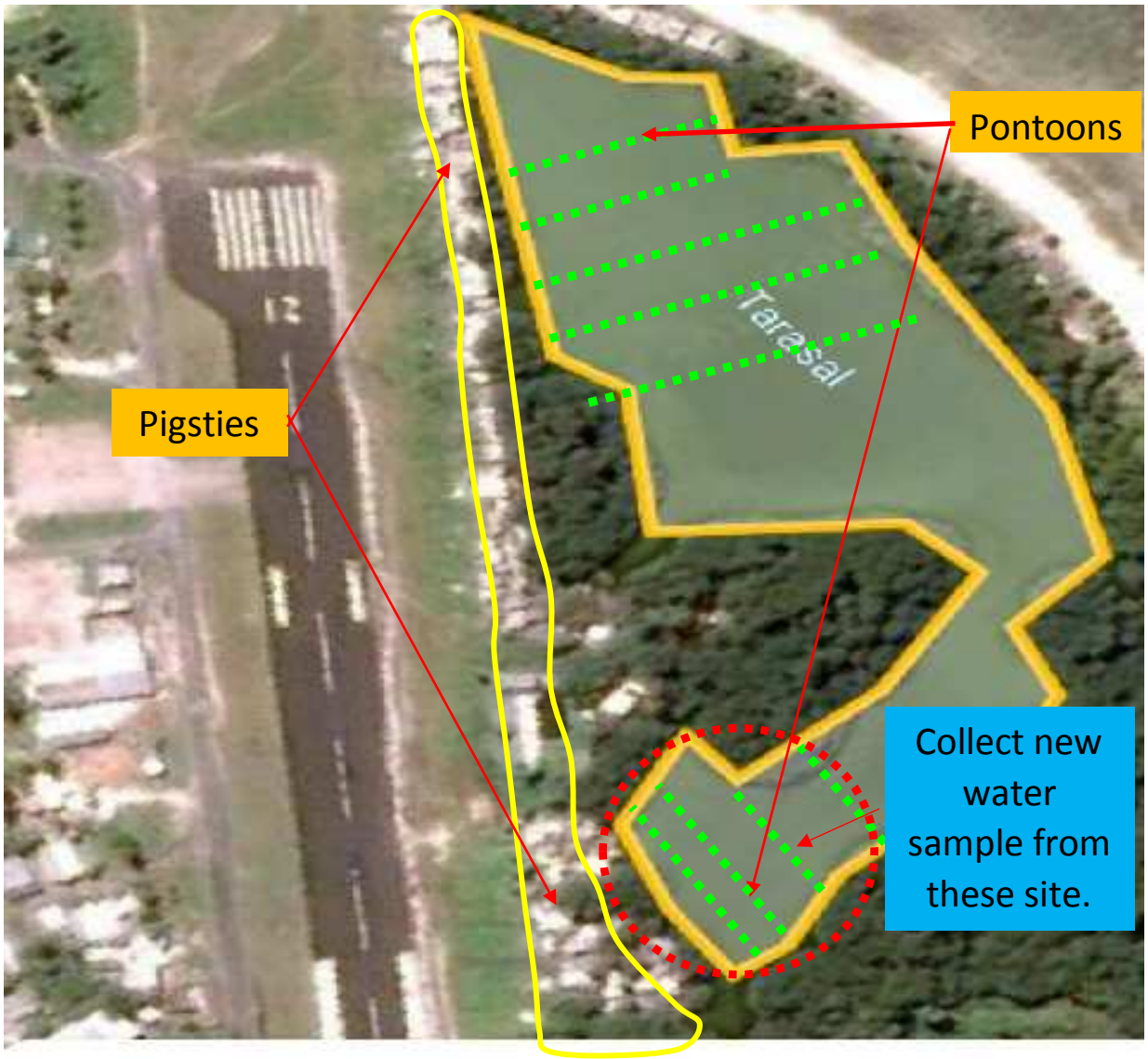
Copyright:

12 **Annex 5:** Map of proposed coastline for protection using Vetiver grass.

13 **Annex 6:** Map of Fualopa Marine Protected Island



14 **Annex 7:** Map of the Tafua Pond



Perimeter

1.04 km

Area

26,265 m²