DISASTER MITIGATION AND VULNERABILITY REDUCTION: AN OUTSIDER'S VIEW*

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Abstract

On 24 October 1998, Atlantic Tropical Storm Mitch was upgraded to a hurricane that developed into one of the strongest and most damaging storm to ever hit the Caribbean and Central America. At its height on 26 and 27 October, the hurricane had sustained winds of 290+ kph and dumped heavy rains over Central America. Although the winds diminished as Hurricane Mitch travelled inland over Honduras on 30 October, the storm continued to produce torrential rains, reaching rates of more than 100 mm per hour. Catastrophic floods and landslides occurred throughout the region. When it was over, some 9 200 people had died; almost 270 000 homes were lost; 21 325 miles of roads and 335 bridges were destroyed. Immediately after the storm, some two million Central Americans were pushed out of their homes. Agricultural losses were staggering. Mitch's impact on watersheds, human lives and the economies of the affected countries will be felt for at least eight to ten years, assuming that another storm of such magnitude does not return. International experts in disaster mitigation and vulnerability reduction rushed to Central America to assist in diagnosing what had happened and what needed to be done. Perhaps, not surprisingly, the majority of their recommendations consisted of things which natural resource and civil engineering professionals have been recommending on a daily basis as being good practice, many being things for which vetiver grass technology is very well suited. Disasters like Hurricane Mitch do not tell us much that is new. But they do focus our minds on what we should be paying attention to in carrying out our professional responsibilities. This paper attempts to pass on some of the lessons learned by one natural resource professional, particularly on where and how vetiver grass technology should play a role in disaster mitigation and vulnerability reduction, as both a bystander and participant in the post-Mitch emergency and reconstruction efforts.

Introduction

Central America occupies an area comparable in size to Thailand. Its 32 million inhabitants live within the seven nations of which the region is comprised: Guatemala, Belize, El Salvador, Honduras, Nicaragua, Costa Rica and Panama. In general, the countries have mountainous interiors surrounded by coastal plains. On the path to urbanization, the population is still predominantly rural and poor. Agriculture remains the main source of livelihood, employment and, generally, is the dominant economic sector.

In the last days of October 1998 Hurricane Mitch, the most intense storm in the Atlantic Basin in the past 200 years and the most destructive hurricane in the history of the western hemisphere (United States Geological Survey 1999), battered the Caribbean coast and parts of Honduras, Nicaragua, El Salvador and Guatemala. From 27 October 1998 to 1 November 1998, it dumped from 300 to 1 900 mm of rain on large areas of the four countries. The storm produced sustained wind speeds of 290+ km/hr and rainfall intensities of more than 100 mm/hr. The main destruction resulted from the intense rainfall.

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* *This paper only represents the perceptions of the author based on experiences coming from involvement with the emergency and subsequent reconstruction program following Hurricane Mitch. It is not a scientific review. However, in writing the paper it was apparent to the author that an effort is required to look systematically at what we know and do not know about the limits to the applications of the vetiver system, particularly as they may relate to design standards. For applications such as those discussed here "VGT for Disaster Mitigation and Vulnerability Reduction", we are looking to see how VGT might perform in extreme events. Inherently then we are talking about limits to the applications, and we simply have not yet adequately defined these limits. Both systematization and synthesis of what we already know, as well as further research, are required.*

The storm's arrival at the end of the rainy season guaranteed maximum damage. In the weeks before its arrival, there had been significant rainfall. Soils tended to be at or near their water-holding capacity. The spring/summer crops were at the point of harvest and the summer/fall cropping cycle was beginning.

Summary of Hurricane Damage

Severe flooding and landslides were widespread throughout the region. More than 9 000 people were killed due to mudslides. Over two million people were left homeless. Much of the transportation and communications infrastructure of Honduras and Nicaragua was devastated. Towers and bridges were destroyed and roads were lost to land sliding or washed away by floods. In Nicaragua, the rain-saturated southern slopes of the Casitas volcano gave way and mudslides reached the town of Posoltega, almost 10 miles away. In Tegucigalpa, the mountainous capital city of Honduras, a landslide blocked the main channel of the principal river. When the dammed river finally broke through, the flood peak washed away entire neighbourhoods; the raging currents undercut city hillsides, bringing other neighbourhoods crashing into the flood waters.

Table 1. Human losses

Country	Person				
	Killed	Injured	Missing	Suffered losses	Evacuated
Belize	n.a.	n.a.	n.a.	n.a.	75 000
Costa Rica	4	n.a	3	16 500	5 500
El Salvador	240	n.a	19	84 316	49 000
Guatemala	268	280	121	105 000	104 016
Honduras	5 657	12 275	8 058	617 831	2 100 721
Nicaragua	3,045	287	970	368 261	867 752
Panama	2	n.a.	n.a	8 408	602
Total	**9 216**	**12 842**	**9 171**	**1 200 316**	**3 202 591**
Equivalent in Thailand [1]	*17 510*	*24 400*	*17 425*	*2 280 600*	*6 084 923*

Source: CEPAL
[1] *Thailand and Central America have roughly the same land area (Central America is 5% larger), and Thailand's population is some 90% greater*

The dimension of damage to the region was (and is) huge. The Central American commercial corridor, about 90-% dependent on road transport, was blocked; intra-regional commerce came almost to a halt. The indirect economic losses ran into the hundreds of millions of dollars. Of the estimated US$6 000 million in direct and indirect losses, about 50% were from the agricultural sector. Flooding, land sliding and sediment inundation primarily affected banana, melon, pineapple, coffee, basic grain and other subsistence crops, and sugarcane; shrimp farm in Honduras were particularly hard hit. Literally tens of thousands of hectares of the region's best agricultural lands were damaged or destroyed, washed away, carried away by landslides, or inundated under deep layers of rock or coarse or sandy sediments.

The deposition of massive amounts of sediments within river courses has caused radical changes in the fluvial morphology and hydrology of many catchments. The hydraulic capacity of the river system has been drastically reduced. In a substantial number of areas, it is unclear where the current (and future) channels of the main rivers are located. In the steep upper watersheds, slope instabilities were activated due to soil saturation. Risks of future flooding and land sliding have greatly increased. This year's rainy season, wetter than normal, resulted in widespread flooding in the cities of the Caribbean coastal plains and land sliding has continued.

Table 2. Economic losses

Item	Damaged or destroyed No.	Economic losses (US$ million) Direct	Indirect	Total
Social		552	247	799
Homes	268 007	436	155	591
Public buildings [1]	1 704	116	92	208
Infrastructure		657	589	1 246
Roads/bridges	34 550 km/335	528	542	1,070
Power generation facilities/power grid	12/n.a.	29	30	59
Water & sanitation system	319	75	16	91
Irrigation system	15	25	1	26
Productive		1 824	2 083	3 907
Agriculture, forestry, fishery	70%	1 702	1 245	2 947
Industry		33	575	608
Commerce & tourism		89	263	352
Environment		67	…	67
Total		**3 100**	**2 918**	**6 018**

Source: CEPAL
[1] *Schools, clinics, hospitals, etc*

Viewpoint of Disaster Specialists

As the true picture of the impact began to emerge, an explanation was sought of what happened and why the impact was so severe. In addition to the understanding that the disaster was the result of a natural phenomenon of extreme magnitude, much attention was focused on the potential role that deforestation and hill-slope farming in upper watersheds had played in "causing" or worsening the impact of the devastating floods. In a real sense, this became the most high-profile issue in the months following. The media focused on how "it seem that Hurricane Mitch has been far more deadly than it need have been, just because the forests were no longer there" (BBC 1998). Government and foreign donor agencies publicly agreed that "the effects of Hurricane Mitch have been increased…in particular [by] the deforestation of forests and wetlands that act as "buffer" system diminishing the surface runoff in the case of such intense rains as those experienced during Mitch" and that "flooding was aggravated by a lack of adequate watershed management" (CEPREDENAC 1999).

In parallel to this more public analysis, international experts in disaster mitigation and vulnerability reduction were assisting to diagnose what had happened and what needed to be done. Radar imagery of flooded areas, overlain on geologic maps, showed that Mitch flooded those areas which are underlain by Quaternary sediments, i.e. those soils formed in areas naturally subject to flooding. Damage assessments increasingly tended to place less emphasis on upper watersheds and deforestation per se and more on the broader issues of:

- *Human mismanagement* – "The risks posed by natural hazards in Central America are exacerbated by social and environmental trends such as rapid urbanization and unplanned human settlements, poorly engineered construction, lack of adequate infrastructure, poverty, and inadequate environmental practices such as deforestation and land degradation." (Inter-American Development Bank 1999)
- *Human encroachment into vulnerable areas* – "People die, are injured or lose their homes in natural disasters because they continue to build and live in unsafe structures and in vulnerable locations." (PADCO 1999)
- *Social vulnerability and poverty* – "Those in poverty typically do not have access to arable and safe land. Instead, they live and farm on marginalized areas, such as floodplains and steep slopes, maximizing their exposure to the next disaster, fuelling the vicious cycle." (PADCO 1999).

The conclusion was inescapable: the disaster that occurred was not a “natural phenomenon”. Or, as put by two anonymous disaster professionals: “Disasters are unresolved problem of development” and “Disasters are indications that we have not yet learned to live where we are living”. Final estimates placed between 50 and 75% of the economic losses from Hurricane Mitch as having resulted from inadequate design and siting of housing, roads, bridges and industry (Inter-American Development Bank 1999).

What was Potentially Avoidable?

Following these conclusions, flowed a long series of recommendations of how to avoid, mitigate and reduce impact from future disasters. To those working in areas related to natural resource management, civil engineering or rural development, not surprisingly, the majority of their recommendations consisted of things which have been recommended on an almost daily basis as being good practice. Indeed, most were basic elements of watershed management and have been a part of the development agenda for decades. Unfortunately, they are also basic elements that tend to be ignored.

We know that good watershed management requires consideration of the many issues that fundamentally influence how humans use natural resources – political, socio-economic, institutional, scientific, technical, community, legislative, regulatory framework, economic incentives, etc – and as such, is extremely complex. However, despite the complexity, in each of these areas one eventually has to come down to getting the objectives right and ensuring that you have appropriate and affordable tools in order to achieve those objectives.

In the specific case of Hurricane Mitch, the lessons learned seemed to point out four main “objectives” that should have been pursued prior to the hurricane in order to have reduced or avoided much of the human tragedy and economic losses. At the risk of oversimplifying, these were:

- Minimize encroachment into flood plains and other elements of the natural drainage patterns, and areas subject to mass movements of earth. Urban, commercial and industrial encroachment into these areas resulted in the greatest losses of human life and of high-value infrastructure and environmental contamination (toxic and hazardous substances washed into rivers).
- Ensure proper design and construction of transport networks. In Honduras, access and transport were returned to pre-1900 conditions. The majority of road and bridge damage and losses were ascribed to poor design, shoddy construction and inattention to stabilization during the construction phase.
- Ensure the adequate protection and proper maintenance of key roads and access points. Lifeline roads and critical access link points were destroyed, leaving large populations isolated and endangered and the economic activities of the affected regions were brought almost to a halt.
- Assist rural households to adequately protect their production system and housing sites. The main economic losses took place in valley agriculture and were a direct result of massive flooding. In the uplands, the main economic impact was in coffee; thousands of hectares of coffee plantations were lost to land sliding. Large indirect losses occurred due to loss of market access roads, forcing producers to leave crops in the field. Smallholder subsistence agriculturalists (the majority of farmers) were extremely hard hit by land sliding, flood torrents carrying away their best streamide lands, extreme soil losses from torrential rains, and loss of crops in the field. Their losses barely enter into the official loss figures. Even with tens of thousands of poor households losing almost everything (house, land, crops), having very little to lose, their losses figure very little in the macro calculations.

The Aftermath: What Needs to be Done?

According to the disaster specialists, the issue now is not “reconstruction”, rather it is “development in the new context created by the last disaster”. From a watershed management perspective, the main challenges in this “new context” seem to involve:

- *Mass wasting* – especially within and near urban or other populated zones where large-scale land sliding has left behind slide zones subject to further land sliding (at the head of slide zones), shearing and collapse (alongside slide zones) and unconsolidated and unstable debris slopes.

- *Shallow slips* – similar to, but much more numerous than, the deeper and larger landslides. Their occurrence is highly correlated with roads and deforested hill slopes. In the most vulnerable upper watersheds of Honduras, where the United States Geologic Survey found occurrences of up to 100 landslides per km^2, preliminary estimates associated some 50 % or more of land sliding with the road system and road cuts.
- *Sediment storage in the stream system* – massive quantities of sediment were mobilized by Mitch, and in some cases riverbeds were raised as much as 10 m. Vast quantities of sediments are now stored within and near stream channels. Over the coming years, these sediment will be flushed through the watershed and, eventually, out to sea. This virtually guarantees continued channel aggradation (rising of stream bottom due to sediment deposition) with associated localized flooding, and re-silting of dredged irrigation canals and river sections for many more years.
- *"Where is the stream channel?"* – River channels are now many times wider than previous to Mitch. In some of the principal rivers, where channels were less than 50 m wide, they are now over a kilometer wide. No one knows where the new river channel might eventually be located. This certainly complicates the siting and construction of bridges, rebuilding of affected urban areas, re-establishment of agriculture, development of water supply system, and numerous other activities.
- *Sediment saturation* – While some benefited, as evidenced by the record melon crops in southern Honduras this year, this was not true for all. Substantial areas of the best lowland agricultural lands have been buried under a meter or more of coarse and sandy sediments whose productive potential is extremely low.
- *Not all future risk can be avoided in new construction* – Roads will still have to go through the mountains, within slide-prone and unstable areas. Homes will be built in unsuitable areas because owners have no other option. Eventually the bridges must cross the rivers and building extra km of road cannot always be justified in order to cross at the best possible bridge sites.
- *Danger zones and encroachment* – Extraordinary efforts are underway to identify areas which are vulnerable and at risk. Land use planning and development of new restrictions and zoning ordinances are underway. At the same time the poor are moving back into the same zones from which they were expelled by flooding and landslides.

Where Does Vetiver Grass Technology Fit In?

If the challenge is to bring about development in the post-hurricane context while ensuring that the hundreds of millions of dollars of official aid coming into the region are used to best advantage, then certainly vetiver grass technology (VGT) has a role to play. This fact is underscored by VGT having been specifically identified as a key technology for post-Mitch construction by the World Bank, the US Army Corps of Engineers, the Inter-American Development Bank, the United States Agency for International Development, CARE International, Chiquita Brands and Tela Railroad Company among others. Also, Mitch finally began to create interest in VGT among the Costa Rican, Nicaraguan and Honduran ministries of Transport. In El Salvador, the work by NOBS Anti-erosion had already ensured that the country's transport and infrastructure ministry is aware of VGT and is seeing it applied. In addition, to promote the use of VGT in post-Mitch construction, the World Bank provided the Regional Unit for Technical Assistance and the Latin American Vetiver Network with a "knowledge management grant". The grant's purpose was to educate key actors and decision makers in the post-Mitch construction (government, donors and private sector) as to the potential, benefits and means to go about incorporating VGT as a low-cost, proven, bio-engineering approach for infrastructure and watershed stabilization.

All that is good. But there is also very limited experience in Central America in the use of VGT, relative to the size of the job ahead. Also, misuse or overselling of VGT can not only result in discrediting the approach, it can also put at risk human lives and high dollar investments. Recently, in a workshop on watershed management in Honduras, an experienced field man spoke up, saying: "We need to systematize our approaches…I am tired of being told 'use vetiver grass' when my problem is something like an actively cutting gully which is 5 m deep and 30 m wide." From this perspective, a brief review of what VGT might be good and possibly not so good for is in order.

What Might VGT Be Good for?

What are the uses and limits for VGT? A number of aspects are worth noting:

- *Stabilizing soil and slopes:* We know from the work of Hengchaovanich (1998) and others (Bracken and Truong 2000; Xiz et al. 1998; Truong 1999) that the vetiver root system is excellent for stabilizing soils. The tensile strength of its roots is high (one sixth the strength of mild steel) and its massive root system greatly increases soil shear strength. Its roots penetrate deeply, even through restricting layers. Its light weight and low wind profile avoid problem associated with greater stress loading on the slope. In term of limits, while the roots may penetrate three to five m, in fact the greatest mass of the root system tends to occur within the top one m or so. As a result, if shear faces or potential failure zones are at a depth below the "effective" depth of the root system, VGT will be ineffective in soil and slope stabilization. If you are going to bet your life or investment on the ability of VGT to stabilize a slope, it would probably be best to desist if the potential failures are likely to occur more than one m below the surface.
- *Trapping sediments:* Quite a bit of work has been done (Rodriguez 1999) on these aspects, including recent (Thurow and Smith 1998) studies in Honduras which showed that traditional slash-and-burn sites average 92 t/ha/year of soil loss compared to 43 t/ha/year with crop residues and a "green mulch" cover crop compared to 0.9 t/ha/year on sites with vetiver grass barriers and the crop residue/mulch. We know it is efficient. We know less about how well or rapidly vetiver can recover from sediment inundation. In Louisiana in the southern United States, for example, vetiver barriers were able to trap more than 50 cm of sandy sediments in less than one year and continue to grow up through them and maintain a reasonably dense barrier. But we also know (personal communication, J. Hellin) that in Honduras "landslides destroyed a number of control plots and [vetiver] barrier plots [i.e. the barriers were washed away]. However, deep-seated landslides only originated on the steep slopes (65-75%). On the shallow slopes (35-45%) the damage arose from debris from landslides which originated on steeper slopes above and outside the research site. In the case of the damage on the shallow slopes, much maize was lost but the vetiver grass, although covered by several inches of debris, survived". On this particular aspect, we have no useful rules of thumb, and any rule would vary based on the growth rate of the plants (a function of climate, substrate fertility, available sunlight, weed competition, etc). To be safe, under conditions where vetiver could be characterized as "growing well", you would not want to rely on hedges to trap more than an average of between 40 and 60 cm a year or trust that they would recover from a complete burial of more than a few cm (10? 20? 30?). For extreme events (e.g. shallow landslides), the expected role of the hedges would probably not be one of trapping sediments per se, rather of stabilizing the slope and reducing the occurrence of shallow slips and hydrostatic blowouts.
- *Reducing runoff velocities:* Flume studies in the United States (USDA/ARS 1991) and flume and field studies in Australia (Dalton et al. 1997) have shown vetiver hedges to be very effective at reducing total head (flow depth and velocity) of water flows. The hedge's effectiveness at doing so increases with hedge thickness (maturity). Little information is available to tell us about the effect of vetiver on total head across a range of slope conditions and flow conditions, especially with turbulent flows. However, it appears that mature hedges can be quite effective at reducing the runoff velocity of flows less than 20 cm in depth, moderately effective with flows up to 35 or 40 cm, and have some impact on flows up to possibly 60 to 80 cm. The important points here are, if the objective is to reduce runoff velocity, that first, a reasonably dense hedge must be established in order to be effective; second, the design flows for which effectiveness might be expected are more likely to be on the order of 5- to 20-year events (versus 100 or 500 year events, as in the case of Hurricane Mitch) or where flows are turbulent, perhaps you might want to expect effectiveness up to around 20

cm in depth; and where flows are laminar up to around 40 cm; and third, given the uncertainty at the moment, it would probably be best to restrict this particular application to non-critical areas (e.g. where failure is not “fatal”).

- *Diverting flow:* Neither does there seem to be much information in this aspect. However, one might suspect that a vetiver hedge’s effectiveness for redirecting flows would probably show similar impact and limitations as it would for reducing runoff velocity.
- *Enhancing infiltration:* Contour vetiver barriers increase infiltration and decrease runoff. This is a very useful characteristic in agronomic situations, but potentially something of a double-edged sword where slope stabilization is concerned. In the latter case, the objective is generally to reduce the amount of soil water, not increase it. In looking at this particular aspect, Hengchaovanich (1998) concluded that more research was required. However, his preliminary results led to the anticipation that vetiver would be able to deplete moisture in the soil, thus lowering pore water pressure – a positive outcome for stabilization; i.e., though more runoff would infiltrate, extractive use by the hedges would more than offset the incremental infiltration. He based this preliminary conclusion on the fact that, in civil engineering uses: (i) slopes will generally be from 30 to 60º; (ii) thus the distance between vetiver hedges would be very small; and (iii) moisture depletion by the hedges on such a slope would be greater. In term of expecting vetiver to enhance infiltration and thus reduce runoff on a scale large enough to reduce downstream flooding: this would simply not be a reasonable expectation, except possibly on extremely small scales (e.g. a 2-ha micro-catchment).
- *Protecting hard structure/soil interfaces:* Experience has shown that vetiver hedges are excellent at protecting the interface between soil and hard structures. This is generally a very vulnerable area. It is here where often runoff is concentrated, causing soil to be scoured away. Often, this is how structures begin to be undermined, leading to the eventual failure of the structure (e.g. gabions along stream channels, bridge footings and “wings” of approaches, concrete drainage channels along roads, etc). This is a truly underexploited use. What the limitations might be is not entirely clear, but as this is a problem for which there are very few alternative solutions, it is worth a try wherever conditions permit to establish a mature hedge.
- *Demarcating areas:* Vetiver is long-lived and, once established, resistant to most things (including being underwater for months at a time) except herbicides, shading, severe weed competition, inundation by sediment, and being dug out of the ground. It is an ideal plant for demarcating areas; nor does it need to be established as a hedge for this purpose.

What Might VGT Be Not So Good For?

Within the uses and limits described above, what might VGT be not so good for? Three aspects appear to merit mention:

- You absolutely cannot save or protect a bad design with VGT. This is basic. If the site is unsuitable, if the road is poorly designed, if the fill slopes are not compacted to design standards, etc, VGT will not rescue the situation. Indeed, it could make it worse by providing a false sense of security.
- You cannot guarantee bad work. VGT has to be applied correctly or it will not work. Others shall be presenting experiences and papers in this conference on this aspect. But if there are any doubts as to what “correctly” means, the vetiver networks are there to assist you to get the details.
- You should not expect VGT to extend the feasible range of where an activity can be carried out, i.e. the purpose of incorporating VGT into activities is not to allow increasingly more risky or vulnerable areas to be used for roads, buildings, houses, etc, but to protect and support well located infrastructure projects.

Pre-Mitch: Where Might VGT Have Reduced Damage?

As mentioned above, there appear to have been four main “objectives” which, had they been more effectively pursued before the hurricane, might have reduced or avoided human tragedy and economic losses. What role might VGT play so that future disasters are less disastrous?

Minimizing encroachment into vulnerable areas: Under Central American conditions it is clear that these areas will continue to be encroached upon. The main impact (loss of human life and economic losses) occurs in urban and peri-urban areas. The use of zoning does not seem to be a very effective option, as non enforcement of laws and statutes and lack of insurance discourage building in vulnerable areas. Indeed, many of the areas hit hardest by Mitch have been identified as "vulnerable" and "high risk" in land use plans and zoning ordinances several times since the 1950s. Such areas need to be put under some economically or socially useful activity which, if wiped out in a flood or landslide, does not cause undue economic loss or human suffering.

In urban areas, these risk zones can be converted by the city or turned over to neighbourhood associations for recreation areas, city parks, sports fields, community gardens, etc. The utility of VGT in these areas would be to protect these areas from the "normal" hazards and maintain their useful life between the more extreme events, through stabilizing river banks and natural drainages, protecting roads and footpaths, redirecting runoff from upper slopes, stabilizing hill slopes and fill areas, etc. In addition, the concept of "social fencing" acts as a deterrent in most Central American societies, i.e. if one can demarcate land (and maintain the demarcation), thus establishing usufruct, this becomes a mild to moderate deterrent to encroachment. Vetiver barriers make excellent boundary markers and are much less expensive to put up and maintain than real fences. "Regular" maintenance, such as twice yearly pruning, would serve to demonstrate continued interest and will.

Proper design and construction of the transport network and adequate protection and proper maintenance of key roads and access points: These two points are substantially the same, the main difference being one of strategy and intensity. In general, proper design and construction require that stabilization of roadsides, road cuts, fill banks, drainage, etc, be taken into account. Without going into details (as there is a whole section in the conference on these aspects), we know that vetiver works well and is low cost. The experience in El Salvador shows this – over 300 km of vetiver hedges were established before Mitch hit to protect roads and other high-value infrastructure: the only failure was in one location where it was discovered that the building contractor had not compacted a fill slope to design specifications. As did the experience in Puerto Rico with Hurricane George, where Mr. Eduardo Mas of the US Natural Resource Conservation Service was reported to have remarked: "The storm were terrible. [Afterward there were] Landslides, roads destroyed, agricultural lands washed away; but, where there were vetiver barriers, everything seemed normal."

Table 3. Some possible applications of VGT in reducing future damage

Criteria	Stabilize soils & slopes	Trap sediment	Reduce runoff velocity	Divert flow	Enhance infiltration	Protect structure/soil interface	Demarcate areas
Minimizing encroachment into vulnerable areas	~		~	~		~	~
Proper design and construction of transport network	x	x	x	x		x	
Adequate protection and maintenance of key roads and access points	x/ ~	~	~	~		x	
Adequate protection of production system & housing sites	x	x	x	x	~	x	

'x' = could have a primary/significant role. '~' = could have a useful secondary/tertiary or very localized role

Road maintenance is always a problem as there is generally little or no budget provided for this activity. Under such circumtances, vetiver is a good alternative. As Mr William Ibarra, a division chief in El Salvador's Ministry of Public Works, explained to the attendees at the World Bank-sponsored Vetiver Bioengineering Workshop: "We never have budget for road maintenance." Therefore his strategy is “to lose fingers, not the hand” by building into the construction phase protection measures which are going to give him long-term, very low maintenance protection in critical areas. He counts vetiver as one of those approaches.

In term of ensuring adequate protection of lifeline roads and critical access link points, this involves expecting disasters to occur and identifying and taking incremental measures to protect key roads and access points. Simply stated, these would be the points where the greatest attention and intensity should be given to see that vetiver is used for stabilization and protection. However, given the criticality of these points, VGT would need to be part of an overall package including hard as well as soft approaches.

Adequately protecting production system and housing sites: The main economic losses having occurred in valley agriculture as a direct result of massive flooding, there is little that VGT could be expected to have done to lessen impact. In the uplands, where thousands of hectares of coffee plantation were lost to land sliding, VGT might have reduced losses by a small percentage. Many of the landslides were deep; tens of hectares sheared off and dropped into the valleys or plantations were wiped out by fast-moving debris and mud flows from upslope.

Smallholder subsistence agriculturalists would be the greatest beneficiary of VGT. Damage surveys noted that virtually all the farm using recommended soil and water conservation techniques (especially, vetiver grass contour barriers, rock terraces, “green mulch”[1] and crop residue management, and an indigenous agro-forestry system[2]) survived Mitch with little damage, while neighbouring farm using conventional practices suffered devastating landslides that destroyed homes and degraded fields.

Simeon Gomez, a hillside farmer in Los Espabeles, Honduras who went through Hurricane Mitch said it best: “On my field with vetiver grass contours, the hillside remained perfectly in place. The fields without grass contours have had their crops and soil washed away.”

Vetiver hedges could also have been somewhat useful in protecting home sites on sloping lands and near minor drainages, especially from undercutting of walls by runoff, and perhaps diverting flows away from the house and reducing sediment damage to interiors.

Post-Mitch: Where Might VGT Be Applied in the Aftermath?

The incorporation of VGT in development efforts might reasonably be expected to assist in dealing with the conditions left behind in many of the watersheds severely affected by Hurricane Mitch. At the same time, it would be reducing future vulnerability and risk. VGT can be used for treating the following situations:

Mass wasting: Many of these are deep slides whose continued instability derives from zones below the depth at which the vetiver root system could affect stabilization, or from huge masses of material still in movement from gravity, or from unstable materials of texture classes (large stones, boulders, etc) for which VGT is unsuited. On the other hand, VGT could play an important, low-cost role in reducing the risk that such instability would trigger. Among the particular applications for VGT here are: (i) in reducing erosion and undercutting of the toe slopes, which generate upslope sliding – establish contour vetiver barriers along the bases of the debris slopes, especially where they contact river channels; (ii) in halting and diverting run-on from upslope which would increase soil moisture and increase risk that slides or shears would be triggered due to increased pore water pressures –

[1] *A cover cropping technique: leguminous cover crop is not incorporated into the soil, rather it is either slashed and the main crop is planted with a minimum till approach either before or after the cover crop is slashed, or the agricultural crop is planted (usually maize, in this case) and the cover crop is planted into the field some weeks after the main crop comes up.*

[2] *The quesungual system is indigenous to the sloping lands in the humid subtropics of southern Honduras: small holder system (<2 ha); natural regeneration (150 to 500 trees/ha); pruning of trees at 1.5 to 2 m; residues and weeds slashed and left as mulch; associated with bean, corn, sorghum; use of 65kg urea/ha with grain crops beans climb or hung on pruned trees; fields are not burned to promote regeneration of trees for the next year. From a farmer’s perspective: reduced labour and costs; conserves soil moisture; fuelwood and mulch from tree prunings; trees provide support to bean crop and for harvested corn.*

establish cross-slope and herringbone-patterned vetiver hedges upslope; (iii) in stabilizing the shallow unconsolidated and unstable shallow debris slopes; and (iv) in stabilizing the soil surface of both the newly exposed areas and the debris slopes such that re-vegetation (natural regeneration or planting) might occur.

Shallow slips: VGT could play a larger role in achieving complete stabilization of shallow slips in: (i) stopping further land sliding and shearing by stabilizing the heads and sides of slide zones; (ii) stabilizing unconsolidated and unstable shallow debris slopes; (iii) stabilizing the soil surface of both the newly exposed areas and the debris slopes so that re-vegetation might occur; and (iv) halting and diverting run-on from upslope to avoid further cutting, shearing, or soil saturation.

Table 4. Some possible applications of VGT in vulnerability reduction

	Stabilize soils & slopes	Trap sediments	Reduce runoff velocity	Divert flow	Enhance infiltration	Protect structure/ soil interface	Demar-cate areas
Mass wasting	~ / x	~	x	x	~		
Shallow slips	x	x	x	x	~		
Sediment storage in stream system	~	~					
“Where is the stream channel?”				~		x	
Sediment inundation	x	x	x				
Not all future risk can be avoided in new construction	~ / x	~ / x	~ / x	~ / x		x	
Danger zones and encroachment	~		~	~		~	~

‘x’ = could have a primary/significant role; ‘~’ = could have a useful secondary/tertiary or very localized role

Sediment storage in stream system: The sheer volume of the sediments involved is such that VGT might only play a very localized role in such things as: (i) trapping sediments to reduce siltation of lowland irrigation and drainage canal system (e.g. in banana plantations); (ii) stabilizing and trapping sediments deposited primarily in ephemeral drainages and first-order stream, and (iii) stabilizing sediments in streamide zones for reclamation as agricultural lands.

“Where is the stream channel?”: VGT could play a modest role in attempting to influence where the future channel might eventually develop. River training works with gabions and concrete walls are extremely expensive and often a complete waste of money. Vetiver diversion hedges at key points would be much less expensive and in the smaller stream system (first and second order stream) could be at least as effective as hard structures in “suggesting” where the channel might develop. Where hard structures are required, it would be recommendable to protect them from undercutting by establishing vetiver hedges along all points of contact between the structure and the soil.

Sediment inundation: In these areas the challenge is to stabilize the soil surface so that the sites can either be reclaimed for agricultural use (e.g. through over-seeding with leguminous cover crops or pasture grasses) or re-vegetated. VGT is an ideal system for this use.

Not all future risk can be avoided in new construction: As previously mentioned, bridges must cross the rivers, roads have to go through the mountains, and some homes will be built in unsuitable areas. In these endeavours, VGT should not be perceived as allowing these to be carried out in newer, even riskier or more vulnerable areas. The appropriate role of VGT here is to extend the design life and safety margin where risk is unavoidable.

Danger zones and encroachment: See *Minimizing encroachment into vulnerable areas*, above.

Post-Mitch: Where Is VGT Being Applied in the Aftermath?

Clearly the impact of Hurricane Mitch has stirred a great deal of interest in VGT. As previously mentioned, a number of multilateral and bilateral donors, NGOs, private companies and government agencies are recommending and promoting its use in their Central American post-Mitch construction. Among them:

- The World Bank – in its ongoing projects in forestry and agriculture, in its new investment program for road construction and rehabilitation, riverbank stabilization, rehabilitation of hydraulic works and irrigation system, and in projects under preparation for watershed stabilization.
- The Inter-American Development Bank – in its ongoing projects for watershed protection for hydroelectric dam and in its new investment program for road construction and rehabilitation.
- The US Army Corps of Engineers – in landslide, gully and riverbank stabilization.
- The United States Agency for International Development – in watershed stabilization and upland agriculture.
- CARE International – in rural road protection and stabilization and upland agriculture.
- Chiquita Brands and Tela Railroad Company – in construction and rehabilitation of drainage canals in banana plantations.
- Costa Rican, Salvadoran, Honduran and Nicaraguan ministries of Transport – in road construction and rehabilitation.
- Panama's National Authority for Reverted Areas – in the Panama Canal watershed for roads, forestry and agriculture.

Will these “recommendations and promotions” result in concrete actions on the ground? Will VGT be applied as a key technology in the aftermath of Mitch? It remains to be seen. At this point, there is simply not enough material in the region to meet the potential demand. The region will have to see a tremendous effort in propagating planting material over the next couple of years if the potential is to be realized. It is now a year later and only CARE and Chiquita Brands have made any significant investments in vetiver propagation.

Conclusion

VGT can play a key role in disaster mitigation and vulnerability reduction. However, we should not get too carried away in defining the potential for its impact. The purpose and role of VGT in disaster mitigation and vulnerability reduction is to protect and conserve, not nature, but our interventions within nature and our attempts to manage nature for our own ends. Extreme events like Hurricane Mitch create conditions that simply overwhelm our works and our fabricated system. As such, VGT is not and cannot be a substitute for appropriate siting of infrastructure, for avoiding encroachment into flood plains and other vulnerable areas, for halting watershed and soil degradation, in short, for overall good natural resource management and land stewardship, for common sense, and for quality designs and construction.

Having said that, VGT can be integrated into our system in order to make them “more resistant” to disaster and “more efficient” at surviving them. It can extend their useful lives between extreme events and increase their margins of safety. The success of VGT in protecting roads and infrastructure in El Salvador and in saving farmers’ fields in Honduras during Hurricane Mitch proves this to be true. And we know it can do so at such a reduced cost that should allow for its much broader application.

Finally, too often we forget, until a disaster comes along to remind us, that it is not enough that we build or design for average conditions. Engineers remember this instinctively. Natural resource professionals often do not, especially those working with the rural poor. We accept soil and crop management system and unprotected feeder roads because we understand the farmer’s and poor community’s logic and time horizon. But what happens when the five-year event overwhelm the pineapple, sugarcane and fallowed strip hedgerows? And the 10-year event the tree hedgerow? And the 25-year event closes the only access road for a year or more? Or, as in the case of Mitch, an even more extreme event forces tens of thousands of rural households off the land and into urban areas whose economies cannot absorb them? Certainly, for the next few years in Central America we are assured that all natural resource management, civil engineering, rural and urban development professionals will be re-evaluating what constitutes "good practice" and comparing it against what they saw happen with their own eyes when Mitch hit. If we can get enough planting material produced and distributed and enough good technicians trained, maybe the next time around VGT success stories will be too numerous to tell.

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