Appropriate Erosion Control Techniques for the Rural Hillsides of Honduras

Meaghan O'Rourke
Appropriate Erosion Control Techniques for the Rural Hillsides of Honduras

by

Meaghan O’Rourke

Committee

Dr. Michael E. Campana, Chair
Dr. William M. Fleming
Dr. Bruce M. Thomson

A Professional Project Report Submitted in Partial Fulfillment of the Requirements For the Degree of

Master of Water Resources
Policy/Management Option

Water Resources Program
University of New Mexico
Albuquerque, New Mexico
August 2004
Committee Approval

The Master of Water Resources Professional Project Report of Meaghan O’Rourke is approved by the committee:

Michael E. Campana, Chair

Dr. William M. Fleming

Dr. Bruce M. Thomson

Dr. Michael E. Campana, Chair

Dr. William M. Fleming

Dr. Bruce M. Thomson

7/15/04

7/15/04

7/15/04
Table of Contents

Acknowledgements........................................p. 4
Abstract..................................................p. 5
Introduction..............................................p. 6
Previous Work............................................p. 9
Goal of the Project.....................................p. 11
Current Conditions.....................................p. 15
Defining Tropical Sustainability......................p. 18
Study Area...............................................p. 20
The Project..............................................p. 21
Data Analysis............................................p. 33
Discussion................................................p. 39
Lessons Learned........................................p. 42
Conclusion and Future Work............................p. 45
Glossary of Terms......................................p. 48
Literature Cited........................................p. 49
Appendix A Average Geological Formation Map........p. 51
Appendix B Erosion Pins................................p. 53
Appendix C Erosion Data...............................p. 60
List of Figues and Tables

Figure 1 Standard home site............................ p. 7
Figure 2 Slash and burn activity....................... p. 8
Figure 3 Project site................................... p. 12
Figure 4 Cultivated hill slope........................ p. 15
Figure 5 Irregular planting pattern................... p. 16
Figure 6 Preferred planting pattern................... p. 17
Figure 7 Landslide..................................... p. 17
Figure 8 Study site with degrees of incline.......... p. 20
Figure 9 Weed roll being constructed................ p. 23
Figure 10 Weed roll................................... p. 24
Figure 11 Degraded weed roll.......................... p. 25
Figure 12 Construction of zacate screens............. p. 26
Figure 13 Zacate planted along contours.............. p. 26
Table 1 Soil sieve analysis for managed site......... p. 28
Table 2 Soil sieve analysis for control site......... p. 29
Figure 14 November day................................ p. 30
Figure 15 Healthy zacate screen....................... p. 31
Figure 16 Trench sediment collection................ p. 32
Figure 17 Start of terrace formation................ p. 32
Figure 18 Erosion pin locations....................... p. 34
Figure 19 Managed site erosion pin data.............. p. 35
Figure 20 Control site erosion pin data............. p. 35
Figure 21 Erosion pin data versus time............... p. 36
Table 3 Erosion rate comparison...................... p. 39
Figure 22 Carmen Peña Cabús and Dalila Sierra..... p. 42
Figure 23 Conversation with patriarch................ p. 46
Acknowledgements

First, I must give thanks and acknowledgment to God, for there is nothing but through Him.

Secondly, I’d like to thank my committee members, Dr. Campana, whom without I never would have seen a world outside of the fragile shell of my own. Also, many thanks go to Dr. Fleming for his calmness and the easy way he enjoys life. Sincere thanks go to Dr. Thomson, whose dry wit is as wonderful and astounding as his stories.

To my Honduran co-travelers, thank you for such a life-changing experience. You all taught me so many things and I will never forget our trip or any of you.

Sincere thanks go to my employer, ATC Associates Inc. Without their support and understanding, this never would have been possible. In addition, a special thanks to Mr. David Offermann, Mr. Toups, Mr. Burt and Mr. Clark for allowing me to pursue this degree. Also, a deep and sincere thanks to Brian and Sharon for working even harder on extra days to be sure the job got done. Brian Britain, thanks for getting me going on this and for your support over the years. Christopher, no this is not a PhD. Michael, take care of your flip-flops.

Of course, loving thanks goes to my mother Shirley for always pushing me to take that extra step and to never be satisfied. I lost you in the middle of this program, but I was never without you by my side.

Thank you goes to Nan, Ma, Pops and Beave for your prayers and gentle guidance when I needed it the most.

And finally (but not least), a tender thank you goes to my Duncan. You’ve seen me through the most difficult parts of this program and in my life. You had to repair doors that I kicked dents in because of homework overload, and you did it with a smile. You fixed computers, made me dinners and took care of the things I was too tired to do. You're such a stable part of my life and I am in such deep respect and have such a high regard for you. I thank you with all of my heart.
Abstract

The rural hillside farmers of Honduras live extremely rudimentary lifestyles with little to no outside income. They choose available parcels of land for their cultivation needs and clear the land using slash and burn techniques. The combination of the steep slopes and the lack of erosion control equates to significant soil loss. The agricultural production determines to the quality of life for the hillside families.

Typical erosion control measures, such as terraces, are exceedingly labor intensive for the rural hillside farmers. The average family lives on a section of land until the soil is no longer productive (between two and five years). This paper characterizes quality of life as having enough harvest to feed the family and additional crop remaining to sell for cash to purchase additional food, medicine and clothing. Once the current worked parcel of land is exhausted, the family must find another plot for its farming activities.

This project implemented an erosion control strategy, using three criteria, on a study site in a readily available part of the land, which is currently used in typical, everyday farming practices. This study addressed the erosion control problems of the rural hillside farmers in Honduras by demonstrating feasible and appropriate erosion control techniques to the farmers. Through the combination of grass screens and trenches located on the down-slope side of the screens, erosion rates seemed to decrease from 0.06 to 0.04 cubic meters of erosion per year. Due to the short duration, limited plot size and possible sources of error, much future work is needed to substantiate these numbers.
Introduction

Morgan and Rickson (1995) defined erosion as "a two-phase process, comprising the detachment of soil materials and their transport down-slope or downstream" (p. 133). It is a concept that can be readily understood by an educated person. But how does one explain the process of erosion and the effects it has on the soils to a non-educated, Spanish-speaking farmer in the rural hillsides of Honduras? This educational difficulty became an integral part of this project. The overall goal of this project was to implement an erosion control strategy, using set criteria, on a study site in that is compatible with current farming practices. However, the education, distance and language barriers would prove to be difficult obstacles in completing this study.

Honduras is located in Central America, bordering Guatemala to the northwest, El Salvador to the southwest and Nicaragua to the southeast. It is a country of approximately 112,000 square kilometers in size (about the size of Alabama). Appendix A includes a geological formation map. Honduras is a developing country with subsistence farming as a requisite survival tool in the rural hillside villages. The native farmers of Honduras live rudimentary lifestyles (Figure 1) with little to or no outside income.
Living in family clusters, the sons and their respective wives stay near the patriarch, sharing in field management duties on the patriarch's land. Sons as young as ten years of age, labor in the hillside parcels in order to maximize crop production.

The harvest provides the majority of their nutritional needs and if possible, additional spending money. If a family is fortunate enough to have enough harvest left over after feeding their large family, they sell the extra for cash. The cash is then used to purchase additional supplies and goods. The yield from their harvests of corn and beans is imperative to their survival.

Rural hillside farmers choose available parcels of land for their cultivation needs. These parcels typically have between a twenty-five and forty degree incline and are cleared via slash and burn (swidden) techniques. Figure 2 depicts a newly cleared area slash and burn techniques in the foreground.
The swidden techniques are detrimental to the soil management and as Juo (2000) states can "create extreme runoff and soil loss" (p. 2). This runoff and erosion ultimately adds to the overall degradation of the region (Thurow & Smith, 1998). The combination of the steep slopes and the lack of erosion control techniques results in significant soil loss. The common problem facing the rural hillside farmer is that after the second year of harvest on a parcel of land, their yield drops to one-fourth that of the first year, due to the "bad soils". This dependence on the land demonstrates that "agroecological conditions are the most important factors determining incomes and natural resource conditions" (Barbier & Bergeron, 2001, p. ix).
Typical erosion control measures, such as terraces, are exceedingly labor intensive. In addition, most of tropical steep lands in Honduras are not deeded properties. The average family lives on a section of land until the soil is no longer productive (between two and five years). Once the current parcel of land is exhausted, the family scouts for another parcel. If the land appears promising and unclaimed, the family unit abandons their current location and relocates to their new stake of land and lays claim to it. This semi-nomadic process does not provide an incentive for hillside farmers to invest an inordinate amount of time building labor intensive terraces or rock walls to protect the soil from erosion.

**Previous Work**

Thurow & Smith (1998) conducted a study by Texas A&M in the rural hillsides of southern Honduras. They had good fortune with farmers implementing a more standard method of erosion control through rocks walls and terraces. Although the study identified the problems, it did little to correct the erosion problems. The study did characterize erosion in the highland tropics as a significant problem that is not adequately addressed because most of the hill slopes and steeplands of the tropics are seen as undesirable for agriculture (Thurow & Smith, 1998). However undesirable, the study concluded, these steeplands constitute more than eighty percent of the occupied areas (Thurow & Smith, 1998).
Further, USAID studies demonstrated that eighty-percent of all grain grown in Honduras is done so on these "undesirable" steeplands of Honduras. Another USAID land-use study documented a ninety-one percent increase in land use in the eleven years between 1972 and 1983 (USAID, 1984). These tropical steeplands are used for cultivation and the erosion from the parcels can be immense, but little has been done to impact the erosion conditions past the characterization process.

Vanacker (2002), in a study of soil erosion in Ecuador, stated that "our present knowledge is especially important for tropical mountainous areas as former research" is in areas with "low to moderate relief" (2002, p. 1). Vanacker continues:

Land use/cover in tropical ecosystems is changing at an ever increasing rate. This has caused important adverse effects on physical and ecological processes; many regions are experiencing at present accelerated environmental degradation in terms of soil erosion, mass movement and reservoir sedimentation (2002).

The lack of research in the area is also due to the unattractive land that is not seen as useful by today's standards. Land with a slope in excess of twelve degrees is not recommended for cultivation by the Soil Conservation Service. The same source suggests that, for reasons of erosion, these lands are unsuitable for development. The
recommendations of the Soil Conservation Service are that steep slopes should be in forest and that their cultivation be abandoned (McHarg, 1992). The option is not that simple for the rural farmers, who rely on this land in order for survival.

Erosion rates in various tropical steep land studies range between can range up to 760 tons per hectare (Thurow & Smith, 1998). It is imperative that the best and most appropriate soil management practices for this tropical region be addressed rather than the best management practice with financial backing.

**Goal of the Project**

The goal of this project was to identify and implement an erosion control strategy, compatible with farming practices. The specific criteria for the chosen erosion control techniques were as follows:

1) The technique must be easy to implement (quick and efficient)
2) The technique must be inexpensive
3) The materials for the technique must be readily available to rural hillside farmers.

The control site was to be directly adjacent to the managed site and would act as a “snap-shot” for the family to have a tangible demonstration of what soil management practices can do for the land (Figure 3).
The Rodríguez family, located in the mountain community of Monte Vista, Honduras, participated in this study. The family has nine sons. Of the nine sons, five are married and live in separate homes. As is typical, the homes of the sons near the patriarch’s (don Marroquin) and they labor daily to maintain their fields as well as parts of the father’s.

In addition to the "picture" the study site could present, the family could also observe how easily these techniques would be put into practice and this would motivate them to attempt to utilize the techniques for themselves. Furthermore, this study attempted to involve the family on a first-hand basis by having them take pictures of the sites’ progress and record the dates the photos were taken. This practice was employed to aid in
instilling a sense of ownership to the family for the project.

With improved erosion control techniques, the rural hillside farmers in Honduras would have a lengthened sustainability, allowing the family to stay in one locale for longer than their current standard. This would help significantly with the environmental aspect of clearing lands for agricultural purposes. The 2.3 percent deforestation rate in Honduras is one of the highest rates in the world. The deforestation rate, combined with the average 2.5 percent population increase exemplifies the need for a family to remain in one place for an extended length of time. This will result in less land that is cleared and used for cultivation (Barbier & Bergeron, 2001). Further, when land is cleared for cultivation, it allows more precipitation to reach the soil with greater “erosive energy” that will be applied to the soil, dislodging it and exacerbating the poor soil situation (Mitchell, 2000).

As a response to the land use, the Honduran government in 1997 declared nearly ten percent of the countryside as protected land for a natural reserve. However, with the continued increase in deforestation for agricultural purposes, even the protected land is being encroached upon for cultivatable land (Encarta, 2004).

Land left with natural vegetation as ground cover holds the soil in place and allows better infiltration into the
soil. Ground cover is needed as an energy diffuser because intense rainfall events combined with erosive and steep hillsides are prime areas for large erosion rates (Thurow & Smith, 1998). It stands to reason that by helping the soil to stay in place, less soil is eroded and allowed to flow downhill as sediment-loaded runoff in the rivers and streams that feed into the Caribbean Sea and the Gulf of Fonseca.

In addition, with even minor soil management practices in place, over an extended period of time, natural terraces and other management techniques would have a better opportunity to form. Erosion should lessen and streams and rivers will begin to improve due to less sediment in their loads.

The soil already in place could sustain current or even improvements in fertility and would therefore increase the yield of the harvest. At a minimum, the nutritional needs of the family would better be met and the overall subsistence of the farmers improved. It is estimated that two-thirds of the children in subsistence farming communities do not receive adequate nutrition at some point in their first five years (Thurow & Smith, 1998). Hypothetically, with a better yield, more cash would be available and the family could better afford to pay for medical care, purchase vitamins, food that is not typically grown, and fertilizers and additional seeds for a more full harvest.
Current Conditions

Currently, the Rodríguez family does not employ any erosion control techniques such as contour planting or fallowing of the lands. A common, cultivated hill slope is pictured in Figure 4.

![Cultivated hill slope](image)

Figure 4
Cultivated hill slope

The family unit cannot afford to allow the land to go unused. The cleared land is always in use in an effort to feed the family, regardless of how meager the crop production may be. The rural farmer clears the lands completely, via swidden techniques for the lower lying vegetation and manual techniques for larger vegetation, such as trees. Trees are perceived as detrimental to the future harvest and as such, all trees in cultivatable land are cut down and the wood is used to build houses or as firewood.
The hillside farmers plant the crops in no particular pattern, using a stick to dig a hole and then dropping the seeds into the hole. There is no hill slope planting contour used which would allow for a lesser amount of erosion to occur. Furthermore, the family plants an entire crop at the same time and does not mix growing seasons of crops. For example, the entire hill slope is covered with corn for the length of the season, rather than planting corn on top of the hill to diffuse precipitation and congruently planting zones of beans in between the zones of corn. An example of such an irregular planting pattern is provided below in Figure 5 and a comparable and preferred planting pattern schematic is presented in Figure 6.

Figure 5
Irregular planting pattern
(from Hesse-Rodriguez, 1994)
Further evidence of erosion and overland flow problems are presented in the form of gullies, rills and landslides throughout the region. A depiction of a common landslide is presented in Figure 7.

More aggressive techniques, such as terraces and rock walls, are seen as too labor intensive and too expensive.
The rural steep land farmers are only able to comprehend terraces as being constructed using rented heavy machinery for the quick erection. The typical northern Honduran field does not produce enough yields to have the additional funds available to be able to pay for the rented machinery. Currently, the family does not have enough manual labor to cultivate the fields they presently utilize, let alone to spend additional time building a "non-necessary" structure that would take manpower away from their crucial agricultural activities.

**Defining Tropical Sustainability**

Sustainability has many definitions, especially when used in the context of agriculture. While five years of agricultural sustainability may be acceptable to the rural hillside farmers of Honduras, the same five year sustainability would be unacceptable to the multi-generational farmer in the United States. A study in tropical tree-crop ecosystems in Malaysia defined sustainable agriculture as including the following elements (Hashim, 1996):

- The efficient use of inputs
- The enhancement of environmental quality
- The maintenance of the natural resource base
- An adequate supply of human food and fibre needs
• Enhancement of the quality of life
• The assurance of profitability

Additionally, soil loss plays an important role in the definition of sustainability (or acceptable soil loss). Soil sustainability can be defined as one to two tons of soil loss per acre per year of average tropical soil genesis. A definition of sustainability includes the theory that soil loss cannot exceed genesis. Based on this, tropical soil loss would need to be less than two tons of soil loss per acre per year (Pimentel, 1993). Without implementing major engineering controls anything less than the current soil loss would be considered to have a greater sustainability than the current situation.

For this paper, the definition that is most applicable to this tropical scenario is a mélange of definitions. James Lein (2003) defines environmental planning as the decision-making process where the planner attempts to achieve a sustainable balance between human needs and environmental protection. Sustainability for the rural hillsides of Honduras is defined, for the purposes of this study, as less soil loss than the current, unimproved, situation. Also included in this paper's definition are the enhancement of environmental quality through erosion control, the maintenance of a natural resource base, an adequate supply of human food and the enhancement of the quality of life. The efficient use of inputs and
profitability requirements in Hashim's definitions are negated as they do not reflect the overall strategy of this paper.

**Study Area**

This project addressed a small rural hillside village located in northwestern Honduras 50 miles north of San Pedro Sula. The homestead in which this project was positioned was approximately two and a half hours (via horseback) southwest from the city of Omoa, at around 2000 feet in elevation. Standard annual rainfall in the area is approximately fifty inches. A study area was chosen with two parcels, side-by-side, on a hill slope of average inclination, which is characteristic of the area and used by the family for farming practices. The two side-by-side parcels were approximately twelve square meters in area and located on a hill slope that averaged thirty degrees (Figure 8).

![Figure 8](image_url)

*Study site with degrees of incline*
The Rodriguez family "owns" this parcel of land and currently uses it for cultivation of maize and beans, the two mainstay crops. The land is constantly cultivated and is not allowed a fallowing time. The family comprehends that crops grow better on flatter land but do not understand the physical processes behind that statement. Currently, that family does not practice any erosion control techniques, such as contour planting, terracing or fallowing time. They do perform a basic lop and scatter technique (cutting and spreading of the organic rubbish on the land) when they weed the crops. Trees in the cultivated parcels are seen as a hindrance by not allowing the sun to shine to the ground for the entire length of the daytime and are hence removed from the land. The family does use a fertilizer when they can afford to purchase it. However, in order to be able to purchase fertilizer, the harvest has to be substantial enough to have produced a sufficient amount of food to feed the family unit as well as to have enough left over to sell for a cash profit.

The Project

The goal of the project was to identify and demonstrate an appropriate erosion control system that met the criteria for this study. The erosion control system needed to be one that:

1) was easy to implement
2) was inexpensive
3) utilized materials readily available to rural hillside farmers.

With these criteria in mind, this study set out to first determine which techniques would be most appropriate.

First, the amount of soil loss for this region was estimated using the Revised Universal Soil Loss Equation No. 2 modeling program (RUSLE 2 ARS Version May 9 2003 from the United States Department of Agriculture Website). Although the estimation would turn out to be an exaggerated overestimate of the actual soil loss in tropical highlands, as was also found by Thurow and Smith in 1998, it served as an initial gage in determining whether or not erosion control was even necessary in the region. RUSLE 2 numbers provided the inference needed to arrive at the conclusion that soil management practices were undoubtedly required.

Next, based on the materials available to the hillside farmers, it was decided that an appropriate control practice would be to install weed rolls on the hill slopes. Unused vegetation, like grasses and weeds, would be gathered, rolled and bundled with twine to form a long roll that would be positioned along the contour of the cultivated hillside. The idea is based on Carter (1993) with further guidance from the International Erosion Control Association (2001).

The weed rolls were selected as the best technique to install because they met the criteria. Other techniques are
terracing, track walking, stair stepping and sheepsfoot rollers (International Erosion Control Association, 2001). However, these techniques all were expensive and difficult to implement, not meeting the criteria for this project.

On the first trip, after some reconnaissance, the study site was located and the weed rolls were explained to the family and put into action in the managed site while the control was left in the natural state. Figure 9 illustrates the construction of one of the weed rolls by Orlando Rodríguez, one of the family’s sons.

![Figure 9](image)

**Figure 9**
Weed roll being constructed

A stake (a sugar cane stem) was driven through the weed roll and into the ground to hold it in place through the rainy seasons. Figure 10 illustrates a weed roll in place.
As well as putting weed rolls into place, erosion pins were driven into the four corners of both the managed and the control areas. The erosion pins consisted of a twelve inch metal pin with a metal washer that was smaller than the head of the pin but large enough to move freely up and down on the pin. The erosion pins were placed to help characterize the amount of soil loss in each site and to compare the managed and the control sites against one another (see Appendix B for photos of erosion pins). Further characterization of the study area also took place including photo collection, regional site reconnaissance and altimeter readings.

On the second trip, the original implementation activities were visually assessed. Unfortunately, in view of the fact that the first activity was inserting natural weed rolls along the contour of the hill slope, the decomposition of the natural fiber rolls was not taken into
account. The original, eight-inch high weed rolls were reduced to only scarcely over one-half inch in height (figure 11).

![Degraded weed roll](image)

**Figure 11**

*Degraded weed roll*

The rolls were still in place and did reduce the overland flow, but certainly not to the extent of the original rolls' potential. There was evidence of weeds, grasses and pebbles that were collected behind the roll, clearly due to a significant amount of rain that fell during the month of November. There was also evidence of overland flow water washing over the rolls and beginning to break down the remnant structure.

During this second trip, it was determined a more aggressive technique needed to be implemented. As such, the weed roll theory was abandoned and a grass screen was put into practice. Best management practices for erosion control in the United States call for the use of vetiver
grass (*Vetiveria zizanioides*) for the use of this filtering technique. The idea behind the use of the grass screen technique is that water runoff will be slowed as it passes through the strips of grass screens. The slowing of the water as it passes through the screen removes some of the energy and forces the overland flow to deposit much of its sediment load on the hedge face of the screen (Grimshaw, 2003).

Zacate grass, a native grass easy to plant and quick growing, was used. Strips of zacate were planted along the contour of the hillside in the managed area (figures 12 and 13). By the end of the week-long site investigation, the zacate had not only taken root but a number of the fast-growing plants had begun to sprout new growth.

![Figure 12](image1.png)  
**Figure 12**  
Construction of zacate screens

![Figure 13](image2.png)  
**Figure 13**  
Zacate planted along contours

In addition to the planting of the zacate grass screens, a small trench was dug on the down-slope side of the screens to act as another depository and energy sink for
overland flow. The premise is that the downhill flow would be slowed by the grass screen, depositing sediment. Then the flow would drop into the trench, losing more energy and depositing the remainder of the sediment into the trench and allowing water to collect along the roots of the zacate further increasing infiltration.

Also on this data collection trip, the erosion rates from the erosion pins were measured. Already, a significant amount of erosion was detectable, in only the two month period between September and November (see Appendix B for photos of the erosion pin measurements). At this point, the soil was also characterized for later use in the Modified Universal Soil Loss Equation. The percentage of coarse, medium and fine grained particles was determined (via sieve analysis) for each plot. The data for the managed site is presented in Table 1 and the data for the control site is presented in Table 2.
<table>
<thead>
<tr>
<th>Sample Number (Managed Site)</th>
<th>Grain Size Percent of Composition</th>
<th>Corresponding Erodibility Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1</td>
<td>80% coarse 15% medium 5% fine</td>
<td>0.24</td>
</tr>
<tr>
<td>Sample 2</td>
<td>75% coarse 20% medium 5% fine</td>
<td>0.28</td>
</tr>
<tr>
<td>Sample 3</td>
<td>60% coarse 15% medium 25% fine</td>
<td>0.20</td>
</tr>
<tr>
<td>Sample 4</td>
<td>60% coarse 15% medium 25% fine</td>
<td>0.20</td>
</tr>
<tr>
<td>Sample 5</td>
<td>60% coarse 10% medium 30% fine</td>
<td>0.16</td>
</tr>
<tr>
<td>Sample 6</td>
<td>75% coarse 20% medium 5% fine</td>
<td>0.15</td>
</tr>
<tr>
<td>Sample 7</td>
<td>50% coarse 20% medium 30% fine</td>
<td>0.21</td>
</tr>
<tr>
<td>Sample 8</td>
<td>60% coarse 10% medium 30% fine</td>
<td>0.16</td>
</tr>
<tr>
<td>Sample 9</td>
<td>80% coarse 10% medium 10% fine</td>
<td>0.095</td>
</tr>
<tr>
<td>Sample 10</td>
<td>65% coarse 10% medium 25% fine</td>
<td>0.17</td>
</tr>
</tbody>
</table>

Table 1

Soil sieve analysis for managed site
<table>
<thead>
<tr>
<th>Sample Number (Control Site)</th>
<th>Grain Size Percent of Composition</th>
<th>Corresponding Erodibility Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1</td>
<td>85% coarse 10% medium 5% fine</td>
<td>0.19</td>
</tr>
<tr>
<td>Sample 2</td>
<td>85% coarse 5% medium 10% fine</td>
<td>0.19</td>
</tr>
<tr>
<td>Sample 3</td>
<td>60% coarse 5% medium 35% fine</td>
<td>0.13</td>
</tr>
<tr>
<td>Sample 4</td>
<td>80% coarse 10% medium 10% fine</td>
<td>0.19</td>
</tr>
<tr>
<td>Sample 5</td>
<td>70% coarse 25% medium 5% fine</td>
<td>0.32</td>
</tr>
<tr>
<td>Sample 6</td>
<td>70% coarse 10% medium 20% fine</td>
<td>0.18</td>
</tr>
<tr>
<td>Sample 7</td>
<td>80% coarse 10% medium 10% fine</td>
<td>0.19</td>
</tr>
<tr>
<td>Sample 8</td>
<td>65% coarse 15% medium 20% fine</td>
<td>0.21</td>
</tr>
<tr>
<td>Sample 9</td>
<td>70% coarse 25% medium 5% fine</td>
<td>0.32</td>
</tr>
<tr>
<td>Sample 10</td>
<td>70% coarse 15% medium 15% fine</td>
<td>0.23</td>
</tr>
</tbody>
</table>

Table 2

Soil sieve analysis for control site

As stated earlier, November was an extremely rainy month and the soils were significantly water logged (Figure 14 illustrates a typical day in November in Honduras).
In order to characterize the soils, they needed to be completely dry for use in a sieve analysis. To facilitate a complete sieve analysis, a total of ten soil samples were needed from the managed site and ten soil samples were needed from the control site. To do this, five samples were collected on two different days from each of the sites. Those five samples were then taken back to the family home and dried in separate cooking pans by the fire for a twenty-four hour period and passed through the sieves. The soil analysis data is provided in Appendix C. The erosion pin data is discussed in the Data Analysis section of this paper.

On the third and final trip to the site in March of 2004, it was ascertained that the November rains had indeed been too much for even the rooted zacate grass screen. The overland flow had uprooted the majority of new plants. The
In order to characterize the soils, they needed to be completely dry for use in a sieve analysis. To facilitate a complete sieve analysis, a total of ten soil samples were needed from the managed site and ten soil samples were needed from the control site. To do this, five samples were collected on two different days from each of the sites. Those five samples were then taken back to the family home and dried in separate cooking pans by the fire for a twenty-four hour period and passed through the sieves. The soil analysis data is provided in Appendix C. The erosion pin data is discussed in the Data Analysis section of this paper.

On the third and final trip to the site in March of 2004, it was ascertained that the November rains had indeed been too much for even the rooted zacate grass screen. The overland flow had uprooted the majority of new plants. The
family replanted the zacate in December and in March the plants were tall and healthy (figure 15).

![Healthy zacate screen](image)

**Figure 15**

Healthy zacate screen

The hill slope showed signs of improvement and healing. A gully that was a significant fixture in the managed site in all previous visits was no longer present (see center of Figure 15). The trench on the down-slope side of the grass screen also confirmed the overland flow had slowed and deposited its sediment load, as anticipated. A build-up of smaller pebbles and fine grain materials was detected in one of the trenches (figure 16).
Moreover, during the last project trip in March of 2004, the trenches were again dug down to allow for added debris deposits to collect. Rocks were placed on the hedge side of the grass as an additional kinetic energy dispersion technique. The beginning of a naturally terraced formation was identified in the managed area as a result of the build up of deposits and debris (figure 17).

Figure 16
Trench sediment collection

Figure 17
Start of terrace formation
Throughout the project, the family was encouraged to participate in a number of ways, which they did through picture taking, asking questions and general interest and observation of the research taking place at the site. The patriarch did not participate in a traditional hands-on method but did ask numerous questions about the project and demonstrated interest in the decisions behind the use of the different techniques and the outcomes of each technique. Follow-up question and answer sessions were performed for the benefit of the patriarch. Once the patriarch understood the objectives of the project, the progress reports of the study traveled throughout the rural community and gathered interest from most of the neighbors. The family continues to participate by taking photos of the project throughout the seven months of continued monitoring.

Data Analysis

Throughout the course of the project, erosion pin data was collected from both the managed site as well as from the control site. The erosion pin data was collected on each trip, measuring the amount of soil loss from the top of the pin head to the washer (figure 18).
The washer acted to average out the surface of the topsoil making a measurement easier to make. Once data was collected from all four erosion pins, the average soil loss was calculated from the area at each site. The individual pin data is presented below (Figures 19 and 20) and in Appendix B.
The period between September and November of 2003 revealed some change in the soil loss in both sites. However, the November to March period showed a remarkable increase in erosion in both the managed site as well as in the control site. This was evidenced from the conversation
with the family as they repaired the damage to the managed site by replanting the zacate. Visually, the increase in erosion was evidenced by the erosion pins (see Appendix B). The data gathered from the erosion pins in the managed site and the control site shows that although there is still a noteworthy amount of erosion occurring in both sites, the amount of erosion in the managed site decreased while erosion in the control site was unchanged. The erosion pin measurements were measured in millimeters, averaged for each site. Then, the average millimeters of soil loss for the four erosion pins per site were used to calculate a volume (cubic meters) of soil loss based on the area of each site (see figure 21).

Site Erosion

![Site Erosion Graph](image)

Figure 21

Erosion pin data over time
This data corresponds to the failure of the natural weed rolls used at the managed site in September and the success of the grass screens and trenches emplaced during the November trip. It should also be noted that the control site shows a continual amount of erosion while the erosion in the managed site has decreased over time.

The Modified Universal Soil Loss Equation (MUSLE) was used to perform the calculations for the soil loss in each site. For the MUSLE, the following parameters are required to calculate Erosion (E) in tons per acre per year:

\[ E = R \times S \times K \times VC \]

Where:
- \( R \) = rainfall erosivity factor for a specific area, usually expressed in terms of average erosion index units (EI)
- \( S \) = slope factor, combining a dimensionless factor for slope length and slope gradient
- \( K \) = potential erosion rate for a specific soil horizon
- \( VC \) = vegetation cover factor, based on percent (per unit) of vegetation that contacts the surface of ground cover (Brooks et al., 2003).

The calculations from the Modified Universal Soil Loss Equations determined the erosion rate in the managed and control sites to be on average 50 tons/acre/year (47 tons/ac/year in the managed area and 55 tons/acre/year in the control area (see Appendix C for calculations). The soil
texture from the managed site, based on the average of ten soil samples was 68% coarse grained, 13% medium grained and 19% fine grained minerals. This composition yields a K factor of 0.19. For the control site, again based on an average of ten soil samples, the soil averaged 67.5% coarse grained, 13% medium grained and 19.5% fine grained minerals for the overall texture. This texture gives a K value of 0.22. The sites are side-by-side, so the relative similarities in K values and soil textures should be similar.

Using the Modified Universal Soil Loss Equation required a number of assumptions. The rainfall factor I was an empirically derived number based from average, non-tropical rainfall events. Although it is possible to calculate a field-measured tropical R value, using Wischmeier and Smith's (1960) Empirical Soil Loss model, this was not performed for this project. Roose (1996) concluded that a greater R value (greater than 100) is rare and published R values are a good approximation to tropical rainfall vents. Thus, it was decided that the empirically derived R value of 100 would be used for this study.
Discussion

Calculated erosion values are considered comparable to those calculated in previous studies. The following table summarizes this statement.

<table>
<thead>
<tr>
<th>Author/Researcher</th>
<th>Size of Plot</th>
<th>Erosion Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>O'Rourke 2004 (Honduras)</td>
<td>12 m²</td>
<td>50 t/ac/yr</td>
</tr>
<tr>
<td>Roose 1996 (Ecuador)</td>
<td>50 m²</td>
<td>127 t/ac/yr</td>
</tr>
<tr>
<td>Roose 1996 (Ecuador)</td>
<td>50 m²</td>
<td>83 t/ac/yr</td>
</tr>
<tr>
<td>Barbier and Bergeron 2001 (Honduras)</td>
<td>Unknown area - 160 m in length</td>
<td>23 t/ac/yr</td>
</tr>
<tr>
<td>Thurow and Smith 1998 (Honduras)</td>
<td>44 m²</td>
<td>307 t/ac/yr</td>
</tr>
</tbody>
</table>

Table 3
Erosion rate comparison

The numbers in the table above from the various studies detail similar slopes in similar tropical regions. The rates have been converted to the same units for ease of comparison with this study's findings.

In retrospect, a greater size of study area would be preferable for the erosion studies. As noted in the Thurow & Smith (1998) study, in the smaller study areas it becomes difficult to view the total effects of erosion on the hill slope, e.g., landslides, rill and gully erosion, etc. However, this study did not want to impose on the lands that are so desperately needed for harvest in order to feed and
clothe the family. It was recognized that whatever area was used for this site, that amount of area would be completely or partially unusable for the family to grow a crop. In an effort to lessen the effects of having the family’s land used, the smallest plot available was chosen.

The goal of the project was to slow the soil loss using techniques that met the predetermined criteria of:

1) ease in implementation
2) inexpensive
3) the materials needed to be readily available to rural hillside farmers.

These criteria were met and initial indications are soil loss may be slowed in the managed site. The techniques used were easy to implement, inexpensive and readily available to the rural hillside farmers. With a reduced soil loss, the soil should retain its fertility for a longer time and this should enable the family to remain at their homestead for a greater period of time, lessening the effects on the environment. It was concluded that the natural weed rolls do not work. However, with evidence of water slowing as a result of the weed rolls, they may work if they were replaced on a very regular basis. The zacate grass screen system reduced erosion in this study. The inclusion of the trenches on the down-slope side advanced the energy dispersion strategy even further (as is evidenced by pebble collection and the start of natural terrace formation). The
rocks located the up-slope side and improved terrace formation can only be concluded as a significant success with additional follow-up work.

Another success that has come out of this study is the awareness of the importance of erosion control in the surrounding communities. Word travels quickly in a small, rural community and so did the news of this study. Carmen Peña Cabús, who is running for mayor of the town of Omoa, the town nearest the village, hopes to use this study as a platform on which to base her campaign. She feels that the rural hillside farmers are often neglected and are overlooked in nearly all aspects of life. Ms. Peña Cabús hopes to base a training program on this study and to use an on-staff agricultural engineer to implement these techniques in rural steep land villages around this city. The agricultural engineer will travel to various villages and work with each village for approximately one month, putting into practice what worked from this study and learning from what did not. Figure 22 shows Ms. Peña Cabús on the right and the agricultural engineer, Dalila Sierra, on the left.
It is with sincere hope that this study be used to give aid and awareness to the rural hillside farmers of Honduras. An awareness that although erosion is a severe problem in their countryside, there are simple ways of addressing it. Maybe, with the help of Ms. Peña Cabús and her assistants, this study will give them a foothold on which to base a program of teaching and implementing techniques that the farmers can use as stepping stones to build and work into their everyday subsistence lifestyles.

Lessons Learned

A small number of difficulties were encountered. The chief concern this study faced was the distance to and from the study site. The remote location limited the amount of data sets that could be collected. Statistically, the more data points the study has, the better the regression with less estimation that is required to complete the analysis.
With regards to the small study area, as previously described, the larger geomorphologic processes that occur on entire hill slopes were difficult if not impossible to identify in a small site. Additionally, to a semi-trained eye, what was able to be detected (such as the start of natural terraces forming) was not necessarily as evident to the untrained eye of the farmer. This made for difficulty in convincing the hillside farmers that the study was actually effective and was not simply taking up room in their crop area.

One of the original theories to this study was that by seeing a woman perform the various tasks required would prove to the rural hillside farmer that the task was easy to implement and that these efforts would be further vindicated by the proven success of the techniques seen in the managed site. The techniques were easy enough to implement through manual labor, but convincing the family the technique was working.

Because this study site was located in the middle of cultivatable fields, it also became a pass through for the farmers to reach the crops above and below the study site. An "untouched" control parcel was impossible to attain. The local children found the erosion pins fascinating and enjoyed playing with the washers. This impact may have affected the data. The location of the study site was located in the center of the farmer's fields, which limited
data collections. For example, an erosion bridge was originally installed in the control site. However, in a typical day of weed cutting and cultivation, the erosion bridge became the victim of a machete attack. The family attempted to replace the bridge, but the children found it amusing to use the legs as make-believe machetes.

The natural vegetation decay rate of the tropical climate was not anticipated and thus the weed rolls were not as successful as was hoped. The weed rolls were nearly decomposed and did not hold their initial structure (6”-8” in height and tightly bound). Due to their composition breakdown, they no longer worked to stop or slow the overland flow by acting like a mini-dam. They were nearly flat but still provided some roughening for the soil surface (slowing some of the overland flow water). Because of the distance in travel to and from the site, this disappointment was not detected until after two months of would-be data collection and in-place management methods were lost.

Additionally, follow-up is earnestly needed for this project. Unfortunately, the rural Honduran farmer perceives the average American that works in the hillsides as coming to work in Honduras to feel better about themselves. Once the American has spent a week or so in the country side, acting like an American, they return home feeling proud to have “helped”. Like so many projects before, the follow-up or on-going work needed for completion of the project falls
by the wayside and nothing is ever seen through to completion. The hillside farmers most often see foreign projects as a burden. However, with true follow-through to the completion of the project, this perception can be eliminated.

Lastly was the impediment of the language barrier. This without doubt, left certain lines of communication veiled in misnomers and hopelessly inadequate translations. Local patois to the Honduran culture was unintelligible to a non-native speaker and thus some information could possibly have been lost in translation.

**Conclusion and Future Work**

Initial indications illustrate the zacate grass and trench system may aid in slowing the erosion rate in the managed area. However, the screening action of the zacate grass was not as superior as that of vetiver grass projects. Studies have shown vetiver grass to reduce soil loss from 143 tons to 1.3 tons/hectare (Grimshaw, 2003). This is not the case in this Honduran study using zacate grass. However, the zacate did meet the criteria that were requisite for implementation of this research.

The limited plot size and short duration of the project limited the usefulness of the study. The plot size of the managed and control areas should be as large as possible, preferably side-by-side (acting as a demonstration plot). Future work should attempt to use an entire hill slope in
order to observe the full effect of all micro-occurrences within the plots. A longer study (greater than two years) with more precise field measurement tools would add to the applicability of this research. Further, additional erosion pins (or other measurement devices) should be located throughout the larger plots in future work. The corner placement of the erosion pins contributes to irresolute data. Future work would also benefit from a comprehensive study in soil nutrient analysis. Although swidden and lop and scatter techniques may return a portion of the nutrients to the soil, it would be beneficial to track the nutrient loss and correlate this with soil productivity.

The side-by-side plots proved to be a helpful tool in demonstrating the possibilities of land management techniques to the hillside farmers. The patriarch began to see the possibilities that come least from contour planting. The photo in Figure 23 was taken on the last trip to the study site.

Figure 23
Conversation with patriarch
The family has decided that with their next crop rotation, they will attempt to carry out the contour planting theory with zacate grass and trenches on at least one of their cultivated hill slopes. Although skeptical at changing their traditions, this new idea will be undertaken.

There is much room for future work, using this research as a baseline study. However, as a closing note it is important to understand the anthropological impacts of future work cannot be overlooked. The farming techniques of the Honduran people are passed down from the generations and are not easily influenced. It would be important to have conclusive, tangible evidence in the side-by-side plots demonstrating the positive effects of erosion control practices (e.g., corn that is twice as healthy in a managed area compared to that in a control area). Then, provide a community training explaining what actions were performed in the managed area. A community-wide change of mindset would better improve the possibilities of long-term erosion control implementation.
Glossary of Terms

**Agriculture** is to raise crops and animals for food, feed, fiber, fuel or other useful products.

**Cultivate** is to prepare for crops or work the soil.

**Deforest** is to remove trees from the land.

**Erosion** is a two-phase process, comprising the detachment of soil materials and their transport down-slope or downstream.

**Gully erosion** is severe erosion in which trenches are cut to a depth greater than thirty centimeters.

**Landslide** is the down-slope movement of soil and/or rock.

**Rill erosion** is the process in which numerous small channels only several inches deep are formed; occurs mainly on recently cultivated soils.

**Sedimentation** is the accumulation of earthy matter (soil and mineral particles) washed into a river or other water body, normally by erosion, which settles on the bottom.

**Swidden** is a technique used to clear forested lands for cultivation via fire (slash and burn).

**Subsistence** is a means of obtaining food and other items necessary for existence.
Literature Cited


Appendix A
Average Geological Formation Map
Continental-marine Study site Unknown

Honduras - Average Geological Formation

Continental Plutonic Marine

Unknown

Study site
Appendix B
Erosion Pins
Control Site
November 2003

Pin 1  

Pin 2  

Pin 3  

Pin 4
Site Erosion

Cubic Meters

Sept. '03 Nov. '03 Mar. '04

Sep. '03 - March '04

Managed Site
Control Site
### Managed site (in mm)

<table>
<thead>
<tr>
<th></th>
<th>Nov. measurements (delta of Sept. to Nov.)</th>
<th>Nov. measurements (delta of Sept. to Nov.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pin 1</td>
<td>0</td>
<td>2.4</td>
</tr>
<tr>
<td>Pin 2</td>
<td>0</td>
<td>2.6</td>
</tr>
<tr>
<td>Pin 3</td>
<td>19.05</td>
<td>3.8</td>
</tr>
<tr>
<td>Pin 4</td>
<td>0</td>
<td>4.5</td>
</tr>
</tbody>
</table>

**Average pin loss (mm)**

|          | 4.80 | 3.3  |

**Cubic meters loss** = average pin loss x plot area (12 sq. meters)

<table>
<thead>
<tr>
<th></th>
<th>Sept. '03</th>
<th>Nov. '03</th>
<th>Mar '04</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.06</td>
<td>0.04</td>
<td></td>
</tr>
</tbody>
</table>

### Control site (in mm)

<table>
<thead>
<tr>
<th></th>
<th>Nov. measurements (delta of Sept. to Nov.)</th>
<th>March measurements (delta of Nov. to March)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pin 1</td>
<td>0</td>
<td>2.8</td>
</tr>
<tr>
<td>Pin 2</td>
<td>-3.2</td>
<td>2.9</td>
</tr>
<tr>
<td>Pin 3</td>
<td>0</td>
<td>0.7</td>
</tr>
<tr>
<td>Pin 4</td>
<td>12.7</td>
<td>3.5</td>
</tr>
</tbody>
</table>

**Average pin loss (mm)**

|          | 2.4  | 2.5  |

**Cubic meters loss** = average pin loss x plot area (12 sq. meters)

<table>
<thead>
<tr>
<th></th>
<th>Sept. '03</th>
<th>Nov. '03</th>
<th>Mar '04</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.03</td>
<td>0.03</td>
<td></td>
</tr>
</tbody>
</table>
Appendix C
Erosion Data
### Managed Site

<table>
<thead>
<tr>
<th>E (tons/ac/year)</th>
<th>R</th>
<th>Slope Factor</th>
<th>soil erodibility (k)</th>
<th>Vegetation cover</th>
<th>Average K</th>
</tr>
</thead>
<tbody>
<tr>
<td>48.8</td>
<td>100.0</td>
<td>7.9</td>
<td>0.19</td>
<td>0.325</td>
<td>0.33</td>
</tr>
</tbody>
</table>

### Control Site

<table>
<thead>
<tr>
<th>E (tons/ac/year)</th>
<th>R</th>
<th>Slope Factor</th>
<th>soil erodibility (k)</th>
<th>Vegetation cover</th>
<th>Average K</th>
</tr>
</thead>
<tbody>
<tr>
<td>55.2</td>
<td>100</td>
<td>7.9</td>
<td>0.22</td>
<td>0.325</td>
<td>0.33</td>
</tr>
</tbody>
</table>