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THE EFFECT OF STONE RETENTION WALLS ON SOIL PRODUCTIVITY AND CROP PERFORMANCE ON SELECTED HILLSIDE FARMS IN SOUTHERN HONDURAS

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EXECUTIVE SUMMARY

Rapid population growth and a corresponding increase in agricultural intensity in the mountainous region of southern Honduras has resulted in a serious loss of forest resources, exploitation of marginal lands, and increasing soil loss due to erosion. Local farming communities, faced with a deteriorating resource base, have responded by increasing the exploitation of steeper, marginal lands and decreasing fallow periods. This has resulted in loss of important forest resources, increased flooding, higher sediment loads in rivers, reduced water flows during the dry season, and depletion of soil productivity.

Farming within the southern area of Honduras has traditionally been carried out through a system of shifting cultivation. Land was cleared of forest and farmed for two to four years, until fertility levels declined to unproductive levels. Soil fertility was restored by allowing land to revert to fallow for a period of ten or more years. Increasing population pressure has led to a reduction of fallow periods, a resulting decrease in the amount of time that soil is protected by vegetation, thus increasing the potential for soil erosion and a decline in fertility. In 1980 fallow periods of five to six years were recorded within the Choluteca watershed. By 1989, the average fallow was less than three years.

In response to this situation, the Government of Honduras and the USAID mission in Honduras initiated the National Resource Management Plan in 1980. Between 1982 and 1989, an important component of this plan focused on activities designed to reduce slash and burn hillside farming practices, encourage conservation, and introduce methodologies and practices for more efficient use and conservation of land and water resources.

In 1990 the goals of the Natural Resources Management Plan were continued and expanded through the implementation of the Land Use and Productivity Enhancement Project (LUPE). During the early stage of this project, more emphasis has been given to the promotion of planting vegetative barriers on hillside farms as concern regarding the large labor requirement for physical barrier construction has arisen.

The purpose of this study is to determine the effect of stone retention walls on soil productivity and crop performance on selected hillside farms within the Choluteca watershed and assess farmer adaptation. The study was conducted on privately owned farms at four locations within the Choluteca watershed.

Sites were located at Texiguat (owned by Emigdio Casco) in the Texiguat watershed, Orocuina (Valerio Sanchez) in the Orocuina watershed, and two at Namasigue (Namasigue 1 owned by Agostina Aguirre, Namasigue 2 owned by Martin Guido) in the Sampile watershed. At each location, test plots were established between stone retention walls on hillside fields. Immediately adjacent to the treated plots, an untreated plot was established in a portion of the field that had not been terraced.

Based on the results obtained from this exploratory study, the following conclusions may be drawn:

1. Terraces built with stone retention walls are effective in retaining topsoil, thus reducing soil loss. Plots utilizing a combination of stone walls and mulch cover showed the least soil movement.

2. The shallow but fertile soils of the study sites are derived from basaltic parent material. At the present stage of terrace evolution, no significant decline in soil chemical properties has occurred. Unterraced plots at Orocuina and Namasigue 2 showed a slight decline in soil organic matter. Soil organic matter content was found to be accumulating directly above terrace walls at all sites.

3. Terracing increased water storage capacity by maintaining greater topsoil depth, creating improved soil through deposition above the stone walls, and producing soils with reduced amounts of coarse fragments.

4. Terracing positively affected grain yield at Texiguat and Namasigue 1. Increase in production was attributed to more available water at both sites in addition to a reduction of erosion induced stand loss at Texiguat. During conditions of drought, soil moisture can become limiting and consequently mask differences in

productivity potential.

5. At all sites, the production of above-ground biomass was greater on terraced plots. This demonstrates that the terraces provide improved growing conditions if soil water is not depleted below critical levels.

6. Problems concerning terrace wall stability arise as soil is redistributed within terraces. Many walls are not protected with vegetation as recommended. Failure to maintain these structures will reduce their effectiveness. Production is negatively influenced by the reduction in cropping area due to the space occupied by retention walls.

7. FAO guidelines do not recommend terraces be constructed on slopes greater than 47%. The sites included in this study as well as many othe farms within the Choluteca watershed are at or exceed the maximum range of applicability for terracing. Further studies are required to determine effective terrace widths as influenced by slope and soil characteristics. Similar studies should be undertaken concerning the use of vegetative barriers for soil conservation.

8. Although this study was exploratory in nature, biomass production, topsoil depth, and soil organic matter appear to be effective indicators for assessing the effectiveness of terraces.

9. Farmers viewed their terraced plots as being more productive. Despite this fact, new walls are not being constructed. The high labor requirement for construction was often cited as an obstacle for constructing new walls. Lack of awareness of soil erosion and its long-term consequences may be an important factor affecting the adaption of soil conservation measures. The construction of stone retention walls and the planting of protective vegetation must be regarded as a communtiy effort. The creating and enhancing of farmer and community awareness of the long-term benefits of soil conservation should be regarded as a major activity of the LUPE project.

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INTRODUCTION

Rapid population growth and a corresponding increase in agricultural intensity in the semiarid, mountainous region of southern Honduras has resulted in a serious loss of forest resources, exploitation of marginal lands, and increasing soil loss due to erosion. A comparison of data on actual land use and availability found that the amount of land considered "eroded" had increased from 397,800 ha in 1972 to 760,000 in 1983, an increase of 91% (Consuplane, 1983). Local farming communities, faced with a deteriorating resource base, have responded by increasing the exploitation of steeper, marginal lands and decreasing fallow periods. This has resulted in loss of important forest resources, increased flooding, higher sediment loads in rivers, reduced water flows during the dry season, and depletion of soil productivity (USAID, 1980).

Farming within the southern area of Honduras has traditionally been carried out through a system of shifting cultivation. In response to a bimodal rainfall pattern punctuated by a dry period of erratic duration, farmers have developed a cropping system of maize (*Zea mays L.*) intercropped with drought tolerant sorghum (*Sorghum bicolor L. Moench*). For landowners with sufficient holdings, cattle also are an important part of the farm system. Traditionally, land was cleared of forest and farmed for two to four years, until fertility levels declined to unproductive levels. Soil fertility was restored by allowing land to revert to forest for a period of ten or more years. Increasing population pressure has led to a reduction of fallow periods, a resulting decrease in the amount of time that soil is protected by vegetation, thus increasing the potential for soil erosion and decline in fertility. Dewalt, in 1980 recorded fallow periods of five to six years. By 1989, the average fallow was less than three years (Stonich 1989).

In response to this situation, the Government of Honduras and the USAID mission in Honduras initiated the National Resource Management Plan in 1980. Between 1982 and 1989, an important component of this plan focused on activities designed to reduce slash

and burn hillside farming practices, encourage conservation, and introduce methodologies and practices more efficient for more efficient use and conservation of land and water resources (USAID).

The Choluteca watershed was selected as the focal point for the project due to its critical state of degradation. Five sub-watersheds were identified (Headwaters, Orocuina, Texiguat, Namale, and Sampile) and managed as administrative units. Technologies promoted for soil conservation included the construction of stone retention walls and hillside ditches as well as the planting of live barriers.

In 1990 the goals of the Natural Resources Management Plan were continued and expanded through the implementation of the Land Use and Productivity Enhancement Project (LUPE). During the early stage of this project, more emphasis has been given to the promotion of planting vegetative barriers on hillside farms as concern regarding the large labor requirement for physical barrier construction has arisen.

Between 1982 and 1989, stone barriers were constructed on a large number of hillside farms through a "Food for Work" program. The purpose of this study is to determine the effect of stone retention walls on soil productivity and crop performance on selected hillside farms within the Choluteca watershed and assess farmer adaptation.

MATERIAL AND METHODS

1. Description of study area

The geographical area of southern Honduras is generally defined by the boundaries of the Choluteca and Valle departments and the southern areas of the Francisco Morazon and El Paríso departments. The region is defined by steep foothills and mountains of uplifted basalt and granite formations which cover 62% of the land area. Most of this highland area lies between 200 and 500 meters in altitude. The original vegetation consisted of deciduous hardwoods with pine forest predominate above 800 meters.

Climate zones within the region range from humid subtropical to semiarid. A bimodal rainfall distribution pattern is marked by an extended dry season from November to April and a period of limited rainfall during July and August. Annual rainfall, which varies greatly within the region and from year to year, averages 1000 mm to 2600 mm. High potential evapotranspiration results in a soil moisture deficit in July and August. Rainfall at Texiguat and Namasigue was recorded using cylindrical rain gauges. Rainfall was measured and recorded daily throughout the growing season by the landowners. Rainfall data for Orocuina was obtained from the LUPE office in Orocuina. Rainfall data appears in Appendix C.

Soils throughout the region are generally shallow with low water holding capacity. Soils classified as Lithic Ustorthents comprise most of the area under maize-sorghum cropping systems. Soils derived from basaltic material are preferred by farmers for their high base status and corresponding high fertility. Slopes with soils of low fertility, derived from granitic material, are avoided if possible or converted to pasture for cattle.

The results of a 1988 survey (Lopez-Pereira, et al., 1990) indicates that over 60% of the farms within the study area are less than 5 ha in size. Dewalt (1981) found that 50% of farmers owned their farms while 3.5% of the population owned 47% of the land.

The study was conducted on privately owned farms at four locations within the Choluteca watershed. Detailed descriptions of each farm can be found in Appendix A.

As no baseline data was available, a paired-plot method was used. At each location, test plots were established between stone retention walls on hillside fields. Immediately adjacent to the treated plots, an untreated plot was established in a portion of the field that had not been terraced. Two replications were conducted at each location, the second replication was located on the terrace level directly below the first replication as shown below in Fig. 1.

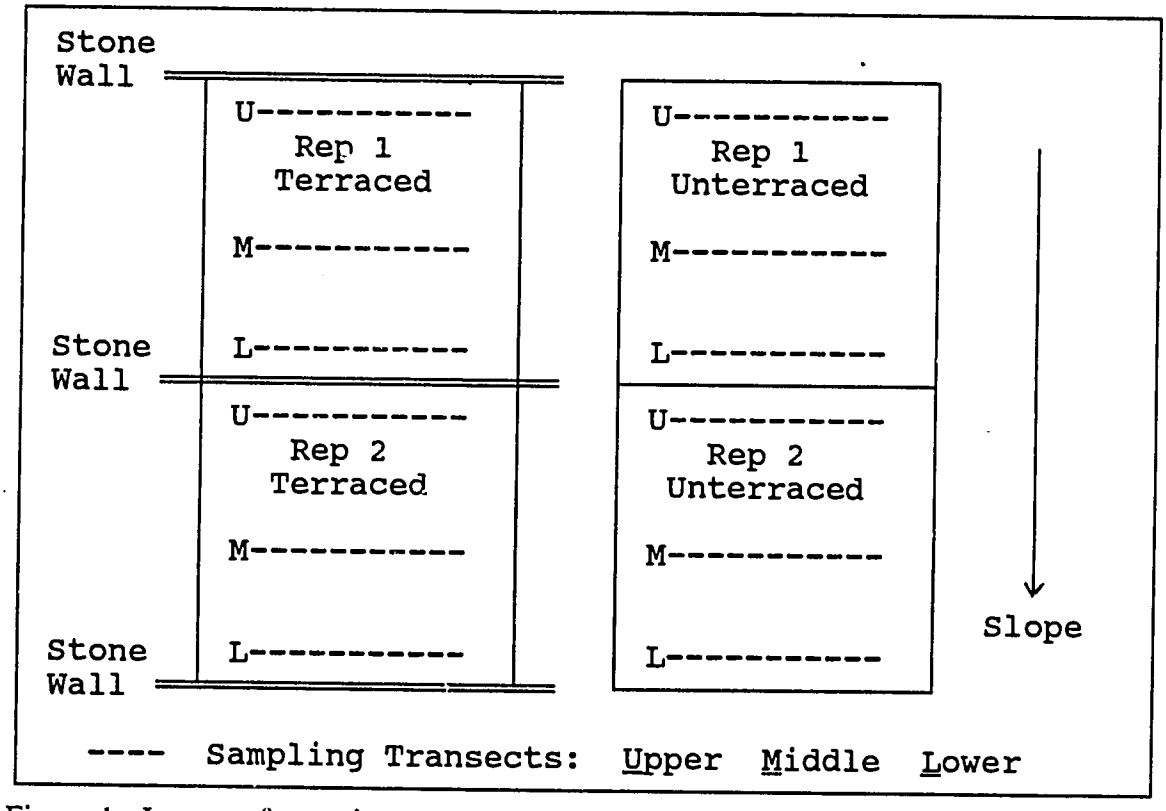


Figure 1. Layout of experimental plots (not to scale).

To minimize experimental error, sites were selected based on the uniformity of slope and soil across all plots within a location. Field surveys and interviews with the landowners were conducted to determine that all plots had similar cropping histories and were presently under uniform management.

Sites were located at Texiguat (owned by Emigdio Casco) in the Texiguat watershed, Orocuina (Valerio Sanchez) in the Orocuina watershed, and two at Namasigue

(Namasigue 1 owned by Agostina Aguirre, Namasigue 2 owned by Martin Guido) in the Sampile watershed.

The stone retention walls at Texiguat were constructed in 1983. The walls at Namasigue 1 were completed in 1984. The Namasigue 2 and Orocuina walls date from 1986. Slopes for the test plots at Texiguat, Orocuina, and Namasigue 1,2 were measured as 54%, 45%, 55%, and 46% respectively. Detailed descriptions of each farm are found in Appendix A.

2. **Soil Sampling Methods**

Measurements of soil properties were conducted along three transects within the terraced and unterraced plots. The upper transect (U) was located within one meter of the upper terrace wall in a zone where soil depletion occurs as soil moves down-slope and accumulation from up-slope is prevented by the stone wall. The middle transect (M) delineated the midpoint between the two terrace walls and represented the largest uniform area within the plot. The lower transect (L) was located in the zone of soil accumulation, within one-half meter above the lower wall.

The transects from the treated plots were extended into the untreated plots for uniform sampling between treatments.

Soil samples were collected from depths of 0-15 cm and 15-30 cm at five locations along each transect. Samples from each depth were then mixed to form one composite sample for each transect.

As the Seccion de Suelos of Recursos Naturales was unable to provide soil maps for the study sites, soils within the test plots were classified based on analysis of soil profiles to 60 cm. Soil classification and profile descriptions for each site are found in the farm descriptions in Appendix A.

3. **Soil Physical Properties**

The effect of stone retention walls on soil physical properties was measured by analysis of the following soil physical properties:

- Texture
- Bulk density
- Water retention at -.33, -1, -5, and -15 bars
- Available water capacity
- % coarse fragment within surface horizons
- % rock on soil surface
- Saturated conductivity (Texiguat and Namasigue only).
- Soil moisture.

Texture of the <2 mm fraction was measured by the Bouyoucos Hydrometer method. Bulk density was determined by the clod method. Texture analysis was conducted at the Secretaria de Recursos Naturales' (SRN) soil laboratory in Tegucigalpa.

Water retention was measured at -.33, -1, -5, and -15 bars by the pressure plate method. Available water holding capacity for the fine-earth fraction was determined as the difference in water retention between -.33 and -15 bars. Field available water holding capacity was determined volumetrically by multiplying values for the fine-earth fraction by soil bulk density and subtracting the soil coarse fragment content. Water retention for the Namasigue 1 and Texiguat sites was determined at the SRN laboratory. Soils for the Orocuina and Namasigue 2 sites were analyzed at Texas A&M.

The percentage of coarse fragments in the upper 30 cm was estimated by visual examination of soil profiles at five locations along each of the sampling transects within the plots. The percentage on the soil surface was measured by sampling at 10 cm intervals along three 6 m long transects randomly chosen within each test plot.

Saturated conductivity was measured by saturating a micro-plot with water by use of a portable rainfall simulator. Runoff from the micro-plot was compared to the total water applied over a fixed time period. Saturated conductivity was measured as the difference between water applied and runoff collected. Saturated conductivity was measured only at the Texiguat and Namasigue 1 sites.

Soil moisture was monitored over the first (Primera) growing season at the Texiguat and Namasigue 1 sites. Soil moisture was measured gravimetrically from samples collected at 15 cm and 30 cm depths at five locations along each sampling transect. Samples were weighed in the field and later dried at 110°C to determine water content. Samples were taken bi-weekly or when weather permitted.

4. Soil Chemical Properties

To measure the effect of stone walls on soil chemical properties samples were analyzed for the following chemical properties:

- Organic matter content
- pH
- Total nitrogen
- Available P
- Exchangeable cations
- Effective cation exchange capacity
- Base saturation.

Analysis for total soil nitrogen was conducted at the Texas A&M. All other chemical analysis was conducted at the SRN laboratory in Tegucigalpa. Organic matter content was established by the Walkley-Black wet combustion method. Soil pH was measured electrometrically on 1:1 soil to water mixtures. Total N was determined by the aluminum digestion block method. Cation exchange capacity, exchangeable cations, and base saturation were measured by the ammonium acetate pH 7 method. Available P was determined by the Olsen (modified) method.

5. Estimation of soil loss

To evaluate the effectiveness of stone retention walls in reducing soil loss, topsoil depth was measured at five locations along all transects in all plots. The amount of soil accumulation above the lower wall of the treated plots was calculated in order to determine

soil movement within the terraces and the ability of stone retention to intercept and retain soil. The difference in topsoil depth between terraced and unterraced plots was used to calculate the amount of soil loss from the control plot for the period since the terraces were constructed.

6. Crop Performance

Crop productivity was evaluated through the measurement of grain yield and total biomass production from 25 m^2 subplots within each treatment plot. Maize ears were harvested and weighed in the field. Subsamples of grain were removed from the ears and tested for moisture with a grain moisture tester. Grain weights were adjusted for ear weight and standardized to 15% grain moisture. Total above ground biomass for each plot was gathered and weighed at each site. Subsamples of 200 g were dried at 65°C to correct for moisture.

Due to problems in coordinating farmer cooperation, the data for the second season (Postrera) harvest was incomplete and will not be used for analysis but is included in Appendix E.

7. Assessment of Farmer Adaptation

Based on interviews with the participating landowners and other farmers within the Choluteca watershed, farmer attitudes toward stone retention walls and the implied impact on technology transfer will be assessed. During interviews farmers were asked the following questions regarding soil conservation. Why had they built stone retention walls? What had been the impact of the walls on crop productivity? What had been the effect of mulching rather than burning? What conservation plans did they have for their untreated fields? What are the major constraints to increasing production?

RESULTS AND DISCUSSION

1. Soil Erosion

Comparison of topsoil depths, shows that soil loss was greater on unterraced slopes at all locations (Table 1).

Texiguat site

The Texiguat site showed the greatest loss of topsoil, equal to 114 t/ha-yr. Extensive rill erosion was evident after every rainfall event. This high loss rate is due to the erodibility of the parent material of the soil, the steep slope, and, crop and soil management. All maize residue is remove from the field and fed to cattle. After threshing, bean residue is scattered unevenly on portions of the field, resulting in a low (17%) mulch cover. Annual, spring plowing may also be affecting runoff. No plowing was conducted prior to this cropping season as oxen teams were not available for hire in time to take advantage of the early arrival of spring rains. Mr. Casco felt the fact that he did not plow this year had led to lower infiltration, greater runoff, and increased rill erosion.

The parcel of land directly above this field is a forested pasture owned by Mr. Casco. It has not been cultivated for the 25 year life of the field under study. Along the boundary between the pasture and the cultivated field containing the test plots there is an abrupt drop in the A horizon depth of 24 cm. This equates to an annual soil loss of 139 t/ha-yr and supports the test-plot observations. Further support was found by measurement of the soil accumulation behind the 1.0 m high, stone retention walls. Accumulated soil had filled to the top of the wall and accounted for a deposition rate of 113 t/ha-yr. Within the terraced plots, slope was reduced from 55 to 50% and slope length between the terrace walls decreased from 6.0 m to 4.5 m. The change in slope length is a result of soil being transported from the top of the terrace and deposited at the bottom, creating a 1.2 m wide, level area directly above the retention walls.

Orocuina site

The annual rate of soil loss from the unterraced plots at Orocuina was estimated

to be 20 t/ha-yr. This corresponds with the soil accumulation which had leveled with the top of the 0.5 m high retention walls. Soil movement at this site may be reduced by the large amount of rock fragments on the soil surface (Table 2), the high organic matter content. The rock fragments, along with a 70% mulch cover provide an effective means of absorbing raindrop energy.

Table 1. Effect of terracing on soil erosion.

Location	A horizon depth Terrace	A horizon depth Unterraced	Soil accumulation behind walls	Soil loss in corresponding unterraced field
	cm		t/ha-yr	
Texiguat	34.6	28.5	113	114
Orocuina	10.3	9.6	29	20
Namasigue 1	13.5	8.9	0	102†
Namasigue 2	8.9	6.3	0	73

†Soil loss for terrace plots: Rep 1 = 175 t/ha-yr, Rep 2 = 29 t/ha-yr

Namasigue sites

Annual soil loss from the from the control plots at the Namasigue 1 site had an extremely large variance. The topsoil depth of replicate 1 was much deeper than the other plots. This is probably due to soil variability. Namasigue 1 and 2 have similar soils and crop management histories. It would be expected that these sites would show similar rates of soil loss.

The Namasigue sites were mulched with a dense layer of crop and weed residue. and weed which provided 78-95% ground cover. Consequently, no significant amount of soil was found to be accumulating above the terrace walls at both Namasigue locations. It appears that a combination of dense plant residue mulch and stone retention walls form an effective means of stabilizing soil movement at these sites. The high rate of soil loss from the unterraced plots suggests that mulch alone cannot stabilize steep slopes. study.

2. Soil Physical Properties

Soil physical properties impact infiltration, soil water retention, and root development. Investigation of soil physical properties presented in Table 2 show that no major changes had occurred at the Namasigue 1, Namasigue 2, and Orocuina sites. The Texiguat site showed a large difference in rock content between the terraced and unterraced plots within the upper 30 cm and a corresponding difference in available water holding capacity. The large difference in rock content at Texiguat can be attributed to the large amount of material removed from the terraced plots for construction of the 1 m high walls and the loss of topsoil from the control plots which is exposing parent material.

Table 2. Effect of terracing on selected soil physical properties.

Site	Treatment	Bulk Density	Rock in upper 30 cm	Available water holding capacity for soil < 2 mm†	Surface rock cover
		g/cm^3	%	cm/cm	%
Namasigue 1	Terrace	1.61	30	.26	18
	Unterraced	1.55	33	.27	19
Namasigue 2	Terrace	1.43	26	.14	5
	Unterraced	1.44	30	.13	14
Orocuina	Terrace	1.48	60	.18	64
	Unterraced	1.45	62	.19	75
Texiguat	Terrace	1.55	46	24	40
	Unterraced	1.51	74	.24	48

†At field capacity

3. Soil Moisture Characteristics

Saturated Hydraulic Conductivity

Saturated hydraulic conductivity is measured as the rate of downward water movement through a soil under saturated conditions. Under field conditions, the flow of water through soils under saturated conditions is primarily a function of pore size distribution. The basaltic soils in this study are extremely well aggregated due to high base status and high organic matter content. The resulting abundance of macro-pores allows for rapid movement of water through the soil profile.

Saturated conductivity data for the Texiguat site shows a high flow rate of approximately 15.5 cm/hr for the unterraced plots. Similar results were obtained on the terraced plots with the exception of the area of soil accumulation above the terrace walls where the mean flow rate was 21.6 cm/hr. This higher flow rate can be attributed to the increase in sand content of the soil deposited above the terrace walls and a higher organic matter content. For the Namasigue 1 location, saturated flow was 26.3 cm/hr for the unterraced plots, 21.4 cm/hr directly below the retention walls, and 23.4 cm/hr directly above the retention walls.

Table 3. Saturated Conductivity.

	Saturated Conductivity	
Plot Location	Namasigue	Texiguat
	cm/hr	
Terrace - Upper Transect	22.4	15.8
Terrace - Lower Transect	23.4	21.6
Unterraced	26.4	15.3

The saturated conductivity tests were completed during the last two weeks of August. At that time, soil moisture at Texiguat and Namasigue was very low (Appendix D). At both sites initial infiltration during the tests exceeded the 30 cm/hr capacity of the rainfall simulator for 1.5 hours, until soil saturation was obtained.

Available water holding capacity

The available water holding capacity of a soil is the amount of water held by a soil, that is extractable by plants, when the soil is at field capacity. At field capacity, all pores capable of holding water against the pull of gravity are filled. In this study, plant available water is measured by the difference between soil water content at -.33 bars and -15 bars.

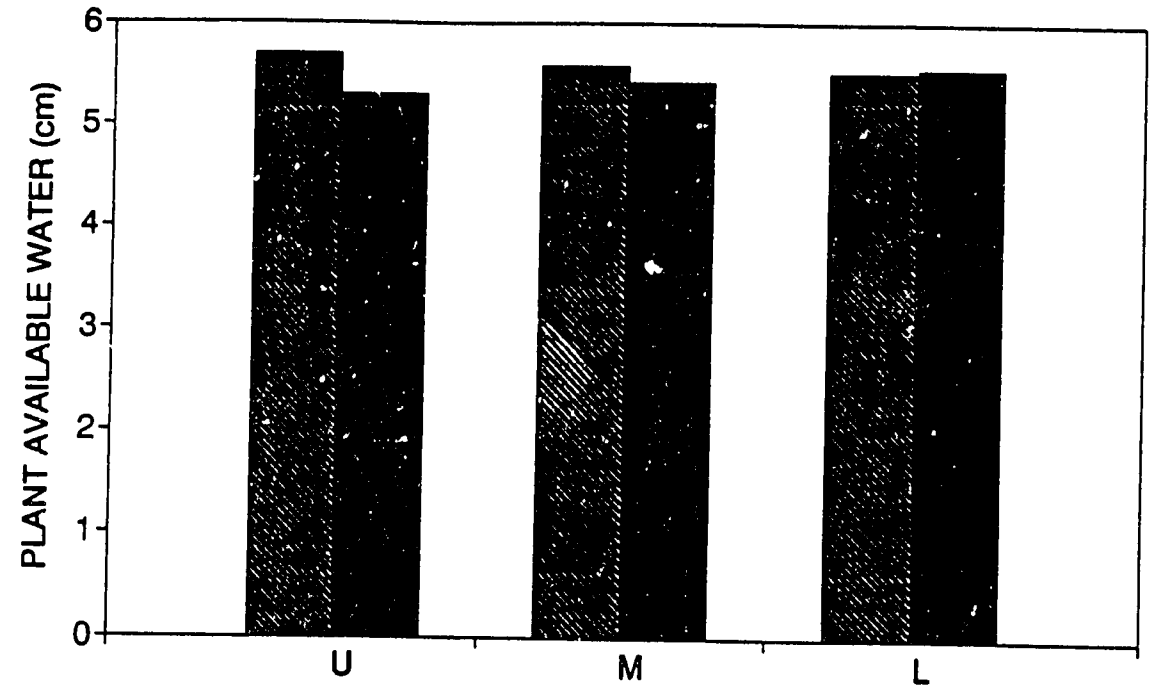
For all sites, no significant difference was found in available water holding capacity values for the fine-earth fraction in the upper 30 cm of soil when terraced plots were compared to control plots (Table 2). However, when available water content was adjusted for the amount of rock material in the soil, the terraced plots at Texiguat showed an increase of 119% (Table 4, Figure 3b).

Table 4. Effect of terracing on available water in the upper 30 cm of the soil profile.

	Available water holding capacity in upper 30 cm of soil profile			
Site	Namasigue 1	Namasigue 2	Orocuina	Texiguat
Treatment	cm			
Terraced	5.5	3.2	2.1	3.9
Unterraced	5.4	2.8	2.1	1.8

The higher rock content on the unterraced plots is due to more rock material being exposed by erosion. The lower rock content in the terraced plots is due to the fact that a large number of rocks were removed from the terraced plots for wall construction, and that the large volume of soil deposited above the stone walls contained no rock fragments. The data shows considerable differences in the ability of the soils at the different sites to supply water to crops. The Orocuina and Texiguat sites have very low storage capacity. Considerably less evaporative losses are expected at the Texiguat site due to cooler temperatures at 780 m.

(a) Namasigue 1



(b) Namasigue 2

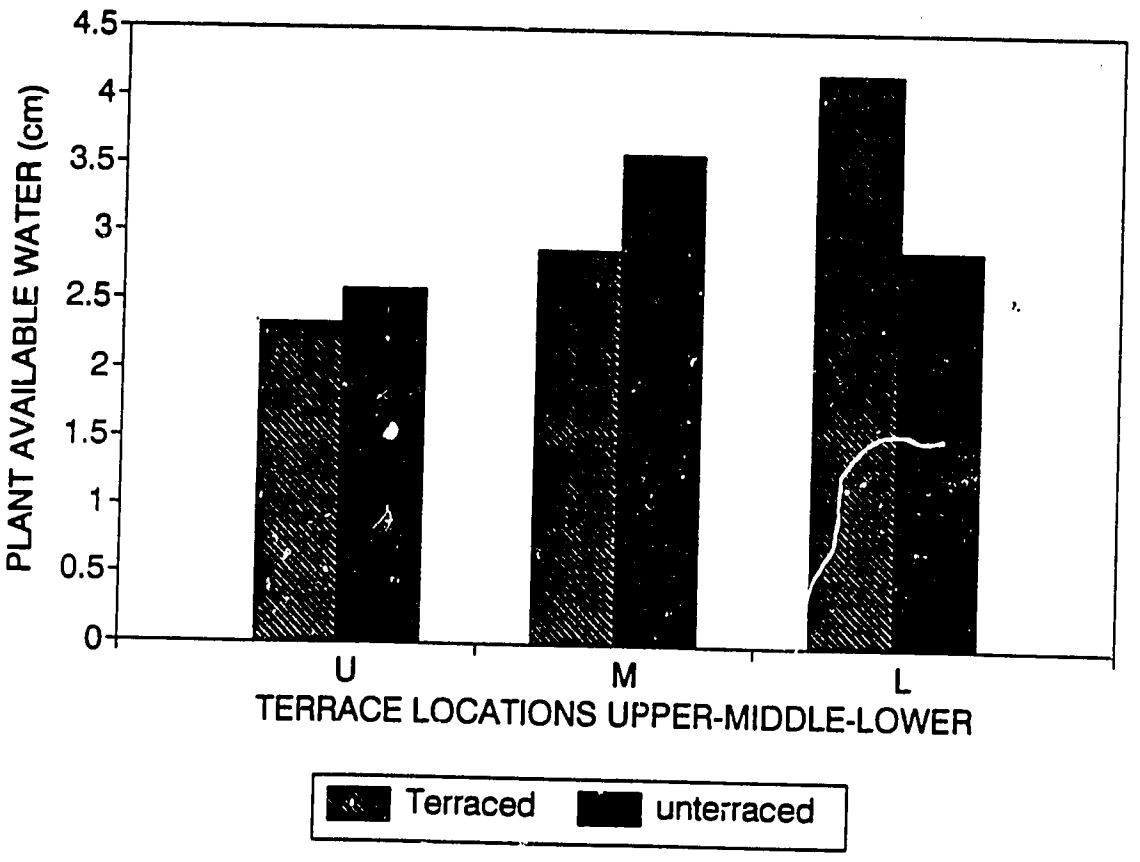
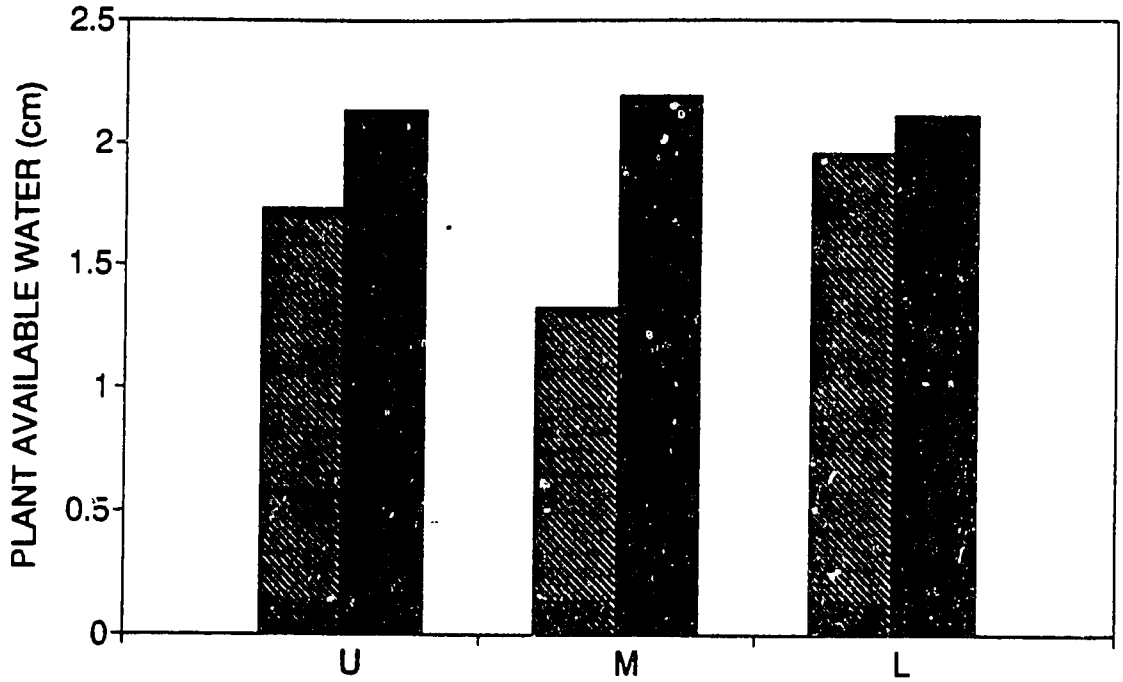


Fig. 2. Available water holding capacity in upper 30 cm of soil profile corrected for rock content for (a) Namasigue 1 and (b) Namasigue 2.

(a) Orocuina



(b) Texiguat

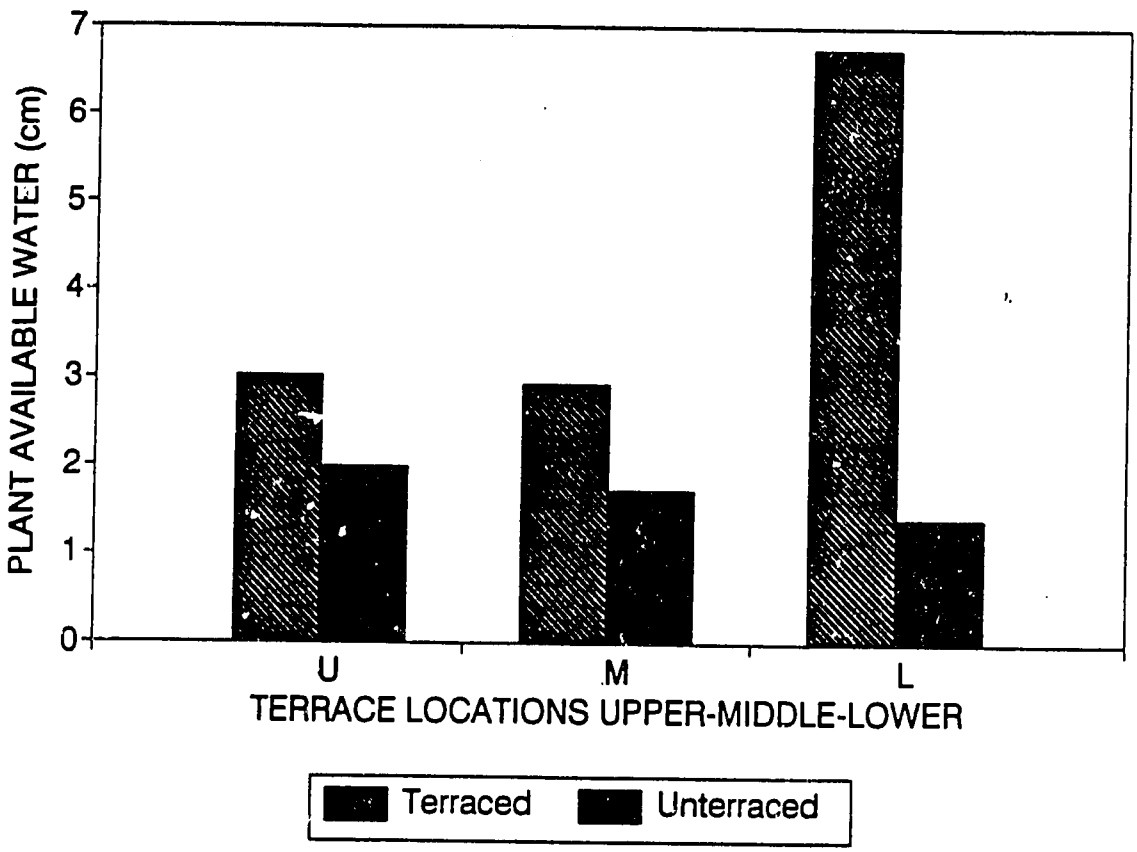


Fig. 3. Available water holding capacity in upper 30 cm of soil profile corrected for rock content for (a) Orocuina and (b) Texiguat.

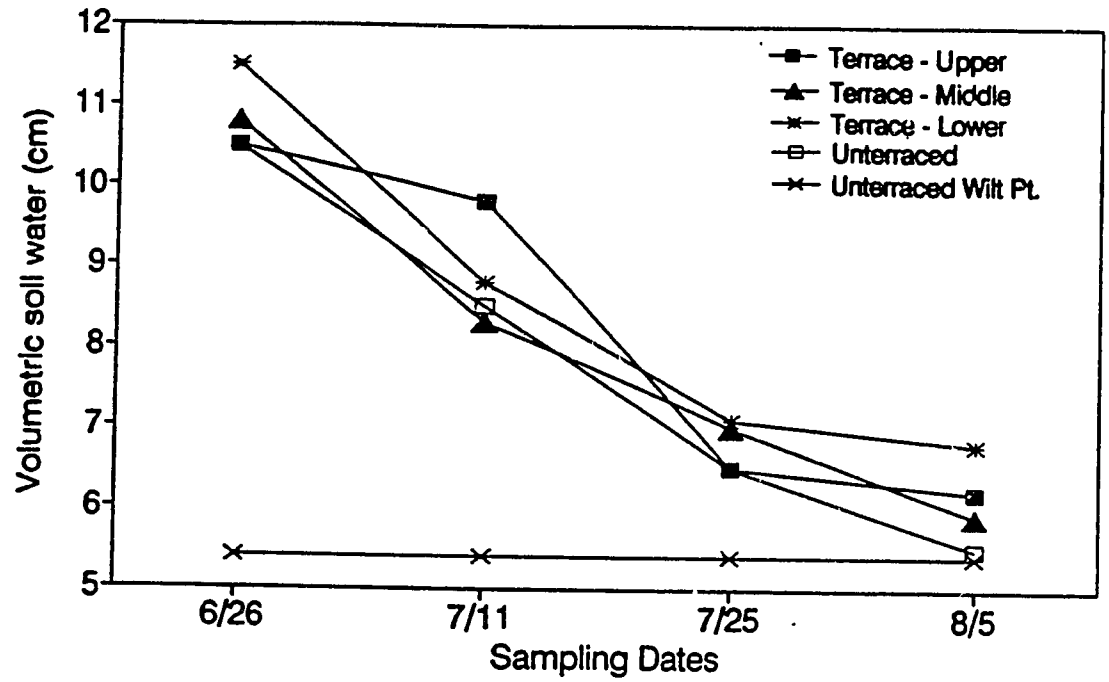
Soil Moisture Content

Field moisture data as measured gravimetrically are given in appendix D. To provide a more meaningful basis for discussion of terrace performance, gravimetric soil moisture contents have been converted to volumetric values using bulk density data and adjusting for soil rock content (Figure 4).

The Namasigue site received only 19 mm of rain during July and 15 mm during August. During all sampling periods, volumetric soil water in the upper 30 cm was found to be higher along the transect immediately above the stone retention walls. The middle and upper transects within the terraced plots showed similar moisture levels as the control plots.

Texiguat received only 26 mm during July and August. Volumetric soil water contents in the upper 30 cm were higher for all terrace locations than the unterraced plots. The lower terrace transect supplied the greatest amount of plant available water during the growing season despite showing lower gravimetric soil moisture levels at 15 cm and 30 cm. The lower gravimetric water content was due to the coarser texture of the soil and the observation that maize and bean growth was much greater along the lower areas of the terraces. Higher growth rates would result in increased water use by the crop.

(a) Namasigue 1



(b) Texiguat

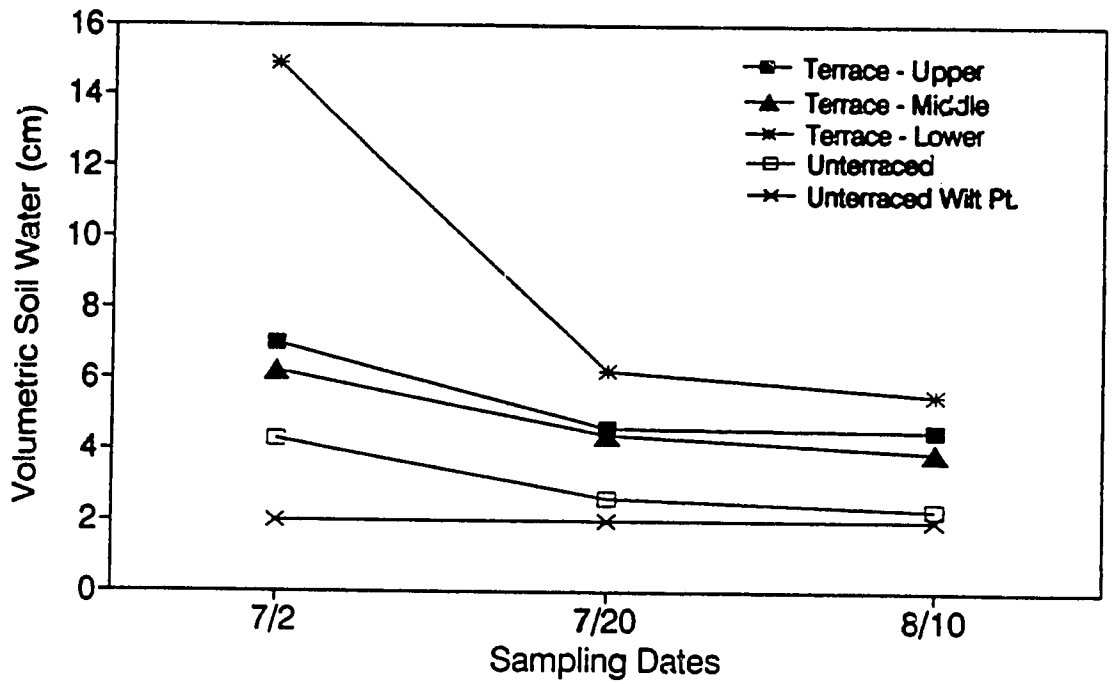


Fig. 4. Volumetric soil moisture for 1991 primera growing season for (a) Namasigue 1 and (b) Texiguat in the upper 30 cm of the soil profile.

4. Soil Chemical Properties

The hillside soils at the study sites are formed on young colluvial materials derived from basalts. Although the soils are generally shallow, they are characterized by a high level of chemical fertility as depicted by high organic matter contents, high effective cation exchange capacity, high degree of base saturation, and high levels of exchangeable cations (i.e. Ca and Mg).

At the present stage of terrace evolution, few changes have occurred in soil physical and chemical properties (Table 5). A decline in organic C was measured on control plots at, Orocuina and Namasigue 2. It is readily apparent that organic matter is accumulating directly above the retention walls in all sites. Plant available P and K also show increased levels directly above terrace walls at Texiguat and Namasigue 2.

Table 5. Effect of terracing on soil chemical properties (0-15 cm).

Site Plot Location	pH	C†	N	P	B.S.‡	CEC§	ECEC¶	Ca^{++}	Mg^{++}	K^+	Na^+	H^+
		(%)	(%)	(ppm)	(%)	cmol/kg						
Namasigue 1												
Upper	6.1	3.5	0.3	6.6	72.7	34.1	25.0	21.5	2.6	0.3	0.3	0.2
Middle	5.5	3.1	0.3	6.0	75.7	31.3	23.8	18.5	4.5	0.3	0.4	0.1
Lower	5.7	3.8	0.3	6.3	76.9	34.6	26.8	20.5	5.3	0.5	0.4	0.2
Unterraced	5.7	3.3	0.3	6.3	79.2	31.4	25.0	19.5	4.6	0.4	0.4	0.2
Namasigue 2												
Upper	5.7	4.0	0.3	4.0	82.7	31.8	26.4	19.5	5.3	0.9	0.7	0.1
Middle	5.7	4.1	0.3	6.0	90.1	31.4	28.4	21.0	5.6	1.0	0.7	0.1
Lower	6.0	4.5	0.3	4.0	89.9	31.7	30.4	18.5	5.1	0.8	0.8	0.2
Unterraced	5.6	3.5	0.2	4.8	84.8	31.9	26.3	19.7	5.1	0.8	0.7	0.2
Orocuina												
Upper	5.6	5.4	0.2	6.3	84.7	34.5	44.1	34.7	7.9	0.9	0.6	0.2
Middle	5.4	4.7	0.2	4.0	76.3	32.0	39.7	32.0	6.7	0.5	0.4	0.1
Lower	5.5	5.8	0.2	6.0	83.9	35.5	44.0	35.5	7.2	0.7	0.4	0.2
Unterraced	5.6	4.2	0.3	4.7	84.3	39.7	38.8	29.3	7.7	0.9	0.7	0.1
Texiguat												
Upper	6.1	2.3	0.2	6.4	94.6	40.4	38.4	29.5	7.1	0.9	0.7	0.2
Middle	6.1	2.3	0.2	5.7	91.0	43.4	39.7	31.0	7.1	0.7	0.7	0.2
Lower	6.1	4.4	0.3	10.5	94.5	40.2	38.2	29.0	7.0	1.3	0.7	0.2
Unterraced	6.2	2.9	0.3	5.4	90.6	43.4	39.4	30.5	7.2	0.7	0.7	0.2

†%C multiplied by 1.72 = organic matter content.
‡BS = base saturation.
§CEC = ammonium acetate at pH 7.
¶ECEC = effective CEC (sum of the cations).

5. Crop Performance

At all locations total above-ground biomass production was lower on the unterraced plots. Grain yield, however, was less responsive to terracing (Table 6). This may be attributed to the rainfall distribution over the 1991 growing season. All sites received adequate rainfall during May and June, the period of vegetative growth for maize. During the grain filling stage in July and August all locations recorded extremely low amounts of rainfall. Thus, drought stress during the critical grain filling stage resulted in minimal differences in grain yields between treatments. The difference in grain yield at Namasigue can be attributed to the extra water captured by the retention walls, which was available during the critical grain-filling period. The positive effect of the higher soil moisture was evident by mid July. Seven weeks after planting, maize height along the lower transects was 122 cm compared to 100 cm for the middle terrace transect and the unterraced plots. Plant height along the upper terrace transect was 90 cm. Measurement of total above-ground biomass production illustrates that the terraced plots were producing more vegetative growth before water became limiting. Observation of uprooted maize and bean plants after significant rainfall events indicated that stand reduction due to the loss of plants to rill erosion was a major factor in reducing plant establishment and grain yield on the unterraced plots at Texiguat.

It is necessary to point out that stone retention walls reduce the land area available for cropping. Wall widths were found to measure approximately 60 cm. For the 6 m wall spacing found on slopes >40%, this represents a 10% loss of cropping area. The net result is that a corresponding yield increase is required to offset this reduction in field size.

Due to the variability in environmental factors affecting crop growth, there is a need for long term studies or monitoring of crop performance, particularly grain yield.

Table 6. Effect of terracing on crop yields.

Location	Vegetative Production	Terrace	Unterraced	% Change	S.E.
		kg/ha			
	Grain	1074	618	73.8	96
Namasigue 1	Stover	1730	1873	-8.3	238
	Total Biomass	2804	2491	12.6	335
	Grain	909	941	-3.4	429
Namasigue 2	Stover	2700	1349	100.1	687
	Total Biomass	3609	2290	57.6	1116
	Grain	855	827	3.4	30
Orocuina	Stover	1572	1027	44.3	9
	Total Biomass	2427	1854	30.9	39
	Grain (Maize)	741	417	77.7	86
	Grain (Beans)	982	550	78.5	216
Texiguat	Stover (Maize)	2912	974	199.0	87
	Stover (Beans)	----	----	----	----
	Total Biomass	4635	1941	138.8	217

If the difference in topsoil depths continues to grow due to greater soil loss on unprotected slopes, the effect of terracing on soil physical and chemical properties will become more apparent as fertile topsoil is lost from the untreated fields. Correspondingly, the effect of terracing on crop productivity will increase as well.

6. **Farmer Adaptation**

Results from on-farm interviews indicate that all of the farmers perceived their terraced land as being more productive than their unterraced parcels. However, none of the farmers in this study seem to recognize soil erosion as a present or potential production problem. Lack of water, and low fertility were given as the main constraints to crop growth. At all sites, farmers recognized that productivity improved gradually over time

following stone terrace construction. The improvement in crop growth was attributed to such factors as the cessation of burning during land preparation and/or the build up of organic matter. Views similar to those above were encountered throughout the Choluteca watershed.

Despite seeing improvements in productivity, none of the farmers have initiated the construction of new retention walls because of the high labor requirements and lack of a community effort. This appeared to be the rule throughout southern Honduras. One reason may be the lack of a means by which farmers can join together and pool their resources for labor-intensive projects such as stone retention wall construction. The negative as

pects of subsidizing farmer cooperation through programs such as food for work are well known. However, these programs provided a vehicle for organizing and sharing labor burdens that farmers do not appear to be able to replicate on their own. During interviews, farmers often cited a lack of ability to organize community effort as a reason for not continuing with construction.

GENERAL DISCUSSION AND CONCLUSIONS

When discussing the effect of terracing, it must be pointed out that FAO guidelines do not recommend terraces be constructed on slopes greater than 47% (FAO, 1977). In effect, the sites included in this study are at or exceed the maximum range of applicability for terracing. Ideally, forestry is the proper land use on these steep slopes. However, increasing population and pressure for farm land have left farmers little alternative but to exploit these soils. Under the extreme conditions of these steep slopes, stone retention walls and other soil conservation technologies require special care in construction and maintenance.

The Texiguat site provides the best example of problems that can evolve. Soil erosion immediately below the walls of the terraces is undercutting the base of the retention walls, causing the structures to collapse. Soil stabilizing vegetation as promoted under the Natural Resources Management Plan was initially planted but did not become established. Although the walls were built to the maximum recommended height of 1 m, the top of the lower wall of a terrace is still more than 1 m lower than the base of the upper wall. It appears the walls are not high enough to accommodate the rapid leveling of the terrace that is taking place. Soil has filled to the top of the walls and water now flows over, adding to the erosion undercutting their bases.

In an assessment of a similar project in Venezuela, Williams and Walter (1988) proposed that a final wall be built to accommodate the final slope conditions (Figure 5). It is doubtful that vegetative barriers could be established in time to salvage the walls at this stage of the problem.

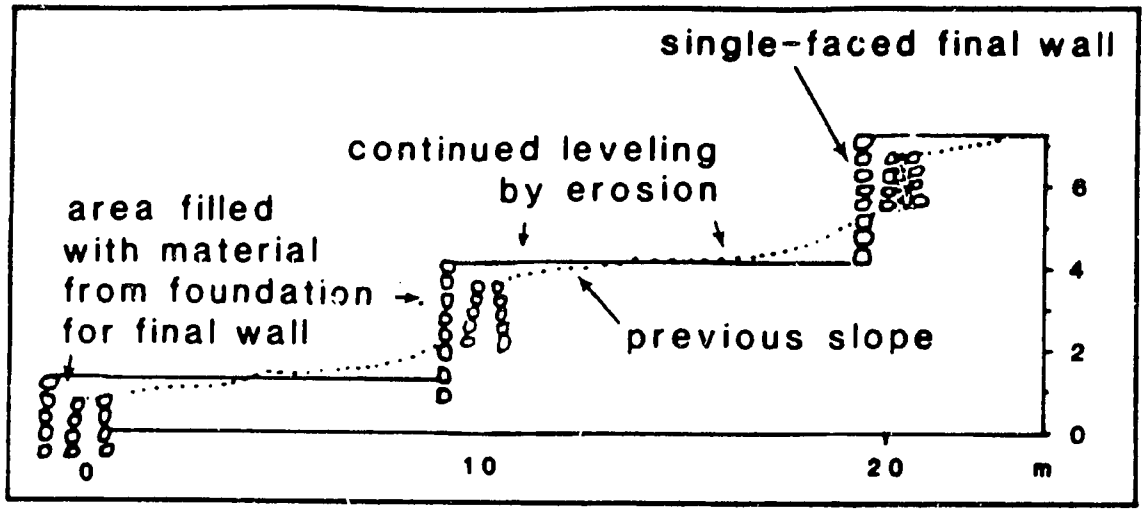


Figure 5. Proposed stabilization of terrace walls (Williams and Walter, 1988).

The walls at the Orocuina site are also filled to capacity with topsoil after five years. The Namasigue sites, while showing very low accumulation rates will eventually meet the same fate. It appears that the 50 cm wall height, common to these sites and throughout southern Honduras, cannot be viewed as a final phase for extreme slope conditions.

As its predecessor project, LUPE is promoting the planting of leguminous trees along the base of stone retention walls. Established tree roots can contribute significantly to the structural stability of terrace walls. However, on very shallow soils such as those found at the Orocuina site, there is a strong possibility of creating competition with food crops for scarce water supplies.

Evidently, there is a lack of understanding by farmers concerning the impact of soil loss and the importance of soil conservation. As discussed earlier, soil erosion was not perceived as a constraint to the farming system. All of the sites have soils with excellent chemical and physical properties. In this regard, farmers are correct when they point to a lack of water as a major limitation to production. However, it appears that the water issue has been narrowly perceived as a rainfall distribution problem. An understanding of the effect of soil properties on plant available water, and the detrimental effects of soil

degradation does not seem to be part of the knowledge base adequately used by farmers to analyze their situations.

The fact that many farmers do not see the effectiveness of stone retention walls in conserving soils, or the long term impact of excessive soil loss, prevents them from adequately evaluating the value of such structures to the farming system. This knowledge gap limits the ability to evaluate effectively the advantages and disadvantages of committing to a new technology, especially if the benefits will not be realized for a considerable time period. When a farmer says that stone retention walls require too much labor, a value judgement has been made based on the perceived benefits in relation to the input costs. If the perception of benefits can be improved through a better understanding of the long term impact of soil erosion and the cost of not implementing adequate erosion control, the likelihood that a successful transfer of technology will occur should increase.

The LUPE project may be facing a similar challenge in its goal of technology transfer through the development of contact farmers who are anticipated to be agents of change in their communities. LUPE is, however, well suited to promote an awareness of the need for soil conservation at the farm and community level through its extension system.

Based on the results obtained from this exploratory study, the following conclusions may be drawn:

1. Terraces built with stone retention walls are effective in retaining topsoil, thus reducing soil loss. Plots utilizing a combination of stone walls and mulch cover showed the least soil movement.

2. The shallow but fertile soils of the study sites are derived from basaltic parent material. At the present stage of terrace evolution, no significant decline in soil chemical properties has occurred. Unterraced plots at Orocuina and Namasigue 2 showed a slight decline in soil organic matter. Soil organic matter content was found to be accumulating directly above terrace walls at all sites.

3. Terracing increased water storage capacity by maintaining greater topsoil depth, creating improved soil through deposition above the stone walls, and producing soils with reduced amounts of coarse fragments.

4. Terracing positively affected grain yield at Texiguat and Namasigue 1. Increase in production was attributed to more available water at both sites in addition to a reduction of erosion induced stand loss at Texiguat. During conditions of drought, soil moisture can become limiting and consequently mask differences in productivity potential.

5. At all sites, the production of above-ground biomass was greater on terraced plots. This demonstrates that the terraces provide improved growing conditions if soil water is not depleted below critical levels.

6. Problems concerning terrace wall stability arise as soil is redistributed within terraces. Many walls are not protected with vegetation as recommended. Failure to maintain these structures will reduce their effectiveness. Production is negatively influenced by the reduction in cropping area due to the space occupied by retention walls.

7. Further studies are required to determine effective terrace widths as influenced by slope and soil characteristics. Similar studies should be undertaken concerning the use of vegetative barriers for soil conservation.

8. Although this study was exploratory in nature, biomass production, topsoil depth, and soil organic matter appear to be effective indicators for assessing the effectiveness of terraces.

9. Farmers viewed their terraced plots as being more productive. Despite this fact, new walls are not being constructed. The high labor requirement for construction was often cited as an obstacle for constructing new walls. Lack of awareness of soil erosion and its long-term consequences may be an important factor affecting the adaption of soil conservation measures. The construction of stone retention

walls and the planting of protective vegetation must be regarded as a communtiy effort. The creating and enhancing of farmer and community awareness of the long-term benefits of soil conservation should be regarded as a major activity of the LUPE project.

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APPENDIX A

Farm Descriptions

I. Agostina Aguirre, Los Espabeles, Namasigue 1

Ownership and size

The Aguirre farm is comprised of 2.8 ha (4 manzanas). The farm is Located in Los Espabeles near Namasigue in the sampile watershed. The altitude of the farm is 250 m. The land is located near the Martin guido farm and was obtained under an agrarian reform program in 1974. The land has been used for livestock grazing or cropping for the past 45 years. The farm supports seven people, two adults and five children. Three pigs were being raised this year along with a few chickens. Two teen boys work in Olancho, picking coffee for two months during the dry season, to supplement family income.

Soils

The soils of the Aguirre farm are derived from dioritic granite. The soil clay is primarily kaolinitic and therefore of low and variable charge. Much of the CEC is due to the organic matter content. The soil at the test plot location was classified as a Typic Haplustalf. A typical soil profile to 60 cm would be described as:

Horizon	Depth (cm)	% Clay	pH
A_p	0 - 10	27	5.7
AB	10 - 27	31	5.2
Bt_1	27 - 45	42	5.7
Bt_2	45 +	54	5.7

Agricultural System

The Aguirre family practices a fallow system whereby 25% or 0.7 ha (1 manzana) of the farm is allowed to rest for three to four years. The current fallow field has not been in crop for the past two years. One manzana was allotted to maize-sorghum relay-cropping during the primera season. The remaining two manzanas were to be planted to maize and sorghum (maicillo criollo) during the postrera season about mid-August. Approximately 0.5 ha are treated with stone retention walls. No land has been burnt since the Aguirre family acquired the farm in 1974. A heavy mulch layer covers 80% of the soil surface. Leucaena trees supplied by LUPE were planted along all stone retention walls in 1991 and will be pruned for mulch and fuelwood.

Cropping system

Land is prepared in march and April by cutting all weeds and brush that has grown during the dry season. Planting of maize ideally occurs during the first two weeks of May. Maize and sorghum are planted in rows one meter apart. Within the rows, holes are made through the mulch with a planting stick at three hand-width intervals (approximately 50 cm). Three maize seeds are planted per hole. In alternate holes, about ten sorghum seeds are deposited. Sometimes sorghum and maize are planted in the same hole. Planting time requirements were estimated at one man-week per manzana. When sorghum is placed in separate holes it is planted in July if rains are adequate. In 1991 no sorghum was seeded due to dry conditions.

Grasses and broadleaf plants were cited as major weed pests. The initial weeding takes place about one month after planting of maize. A second weeding will be made in August to release the sorghum crop. The herbicide 2,4-D was employed for the first time in 1991. The sprayer was supplied by the Namasigue LUPE office. Weed control was poor and the Aguirres stated they probably wood not use a herbicide in the coming year. It was estimated that hand-weeding requires 14 man-days per manzana.

Major pests included Langostas (fall army worm and looper species), Gaillinas

(white grubs), and Cogolleros (stem borer). Seeds were treated with Contra (Counter) as a protection against ants and termites. No one in the Aguirre family has training in the handling of pesticides.

If the weather is rainy at harvest time the stalks are bent over so that the ears hang downward to facilitate drying. Once the ears have been harvested, the stalks are cut and left as mulch in the field. Sorghum is harvested in January. Heads are cut from the plants and threshed.

Grain is stored in sacks and suffers damage to weevils and fungus. Maize is reported to store better if it is left on the ear.

Lacking an adult male, the Aguirre family is dependent on its two teenage boys to supply most of the labor for crop production. It appeared that they were not able to keep pace with the demands of the seasons. Much of the land did not get seeded until early June. By the time they were prepared to plant sorghum the rains had quit and no sorghum was planted. Weeding fell behind the stated schedule and some fields received no weeding. The grain yield from the farm is barely enough to support the family. Senora Aguirre stated that the addition of three small pigs stressed grain supplies to the point where stocks nearly expired before the 1991 maize harvest.

Soil Conservation.

The Aguirre family views the terraced field as their best land. They saw no difference in crop yields during the first year. Since then, they feel productivity has increased a little every year. The increase in productivity is attributed to higher levels of organic matter on the terraced slopes. They have not built new terraces since 1984. Lack of rock and the need to pursue off-farm income were given as major constraints.

II. Martin Guido, Namasigue 2 (Los Espabeles)

Ownership and size

The Guido farmed is located at Los Espabeles, near Namasigue, in the Sampile watershed. It is comprised of 2.8 ha (4 manzanas) of non-contiguous holdings. The altitude of the farm is 230 m. This land was obtained through the break-up of a large land-holding under a Honduran government agricultural reform program in 1974. Mr. Guido claims to be familiar with his land's history and claims it has been continuously used for crop and livestock production during the past 45 years. This farm supports 11 people, two adults and nine children. Livestock included one horse and 10-15 chickens.

Soils

The soils of the have developed from the same parent material and under similar pedogenic conditions as the soils of the Aguirre farm. The soil from the test plots was also described as a Typic Haplustalf with a soil profile to 60 cm as listed below.

Horizon	Depth (cm)	% Clay	pH
A_p	0 - 10	27	5.7
AB	10 - 24	33	5.5
Bt_1	24 - 42	44	5.7
Bt_2	42 +	53	5.7

Agricultural System

Each spring (primera season), 2.1 ha (3 manzanas) are planted to sorghum (maicillo criollo) relay-cropped with maize. Maize and sorghum (maicillo criollo) are planted at the end of April whether the rainy season has begun or not. Another 0.7 ha is planted to maize and sorghum with the onset of the second rainy period (postrera) in late September. All land is under production; no land is set aside for fallow as the family feels hard pressed to meet its grain requirements. A small patch (less than .1 ha) was planted to beans though beans do not grow well in this area. A small portion of the land (approximately 0.15 ha)

has been improved with stone retention walls. Leucaena trees were planted along the base of the walls at one time but have died, leaving a few scattered survivors which are pruned for mulch in April. With the exception of stalks fed to the horse, all crop residue is returned to the soil as mulch. A heavy mulch layer covers 95% of the soil surface. A few fruit trees are grown for home use. Species include orange, mango, papaya, and banana.

Cropping System

Land is prepared each March and April by cutting the small brush and weeds that have grown during the dry season. No burning has been used since Mr. Guido began working with extensionists from NRMP in 1986. Mr. Guido estimates that 16 man-days are required for land preparation.

Maize and sorghum are planted in alternate rows 85 cm apart. Within a row, maize and sorghum are planted at 45 cm intervals at a rate of 2 seeds per hole for maize and 3-4 seeds per hole for sorghum as recommended by LUPE extensionists. The farmer feels that this method is superior to his old seeding rate of 4-5 maize seeds and 10-15 sorghum seeds per hole at a spacing of 1 m x 1 m. Planting is carried out by making a small hole through the mulch and into the soil with a pointed planting stick.

Mr. Guido stated that weeds were controlled with weedings at 20, 45, and 70 days after planting of maize. One complete weeding (limpia) of the farm requires 8 man-days. Grasses and vines are considered the most serious weeds. A herbicide, 2,4-D, has been used every year for the past six years during the first weeding period. It is applied with a backpack sprayer supplied by the LUPE office. The application rate is 1 liter/ manzana. Major pests included Langostas (fall army worm and looper species), Gaillinas (white grubs), and Cogolleros (stem borer). Tomaron insecticide was used for control of stem borers. Seeds were treated with Contra (Counter) as a protection against ants and termites. Mr. Guido has no training in the handling of pesticides.

Once the maize crop has reached physiological maturity, the stalks are bent

downward near the ear to facilitate drying of the grain. This, it was explained, was not necessary during the postrera season.

Grain is hand picked and stored in sacks. Mr. Guido reports storage problems with fungus and insects. He will not harvest within three days of a new moon as he feels this will increase the previous mentioned storage problems. All grain is consumed on the farm.

Soil Conservation

Mr. Guido decided to build stone retention walls after visiting another farm on a field trip. He reports no difference in crop yields the first two years. Since then he has seen some improvement which he attributes to mulching with leucaena and not burning. Mr.Guido feels that mulching is the key factor to successful soil management. Mr Guido plans to build more walls during the next dry season through collaboration with his neighbor, Miguel Gomez who is a highly supported LUPE cooperator.

III. Valerio Sanchez, Orocuina

Ownership and size

The Sanchez farm is located near Orocuina in the Orocuina watershed at an altitude of 350 m. The farm is comprised of 10 manzanas (7 ha) and equally shared by the families of the three Sanchez brothers. The land was obtained from their parents who in turn had purchased the parcel from a previous owner. Mr. Sanchez estimates that the land has been employed in an agricultural production system for ninety years. The farm supports twenty-five people, six adults and nineteen children. Livestock is limited to two pigs and 30 chickens.

Soil

The soils of the Sanchez farm have evolved from basalt. The soils are characterized by extreme shallowness, high in organic matter content and very low water holding capacity. Coarse fragments filled 80% of the soil volume at a depth of 15 cm. The fine earth fraction (<2 mm) is characterized by excellent physical and chemical properties. Crop production is limited by the very low water holding capacity due to the shallowness of the of the soil and the large percentage of coarse fragments.

The test plot soil was classified as a Lithic Haplustalf. A typical soil profile would be described as follows:

Horizon	Depth (cm)	Clay (%)	pH
A_p	0 - 9	26	5.5
A	9 - 15	26	5.5
Bt	15 - 22	35	5.5
R	22 +		

Agricultural system

The Sanchez families practice a fallow system of land management. Approximately half the land is presently in fallow. The brothers feel that a ten year fallow period is

required to reestablish fertility after cropping. However it is felt that the field that has been improved with stone retention walls will only require a fallow period of two to three years. The treated field has been in production for four years. The remaining fields have been in production for the past eight years. In two years they will be abandoned and the fallow land will be cleared and seeded. Isolated trees (Gliricidia and Leucaena) are found in some fields. They have been allowed to grow and will be used for building construction when required. All crop land (4.5 manzanas) is seeded to a mix crop of landrace sorghum (maicillo criollo) and maize (*Zea mays L.)*. A small patch of beans was tried under a LUPE program. Beans are usually purchased as they do not grow well under present conditions. Small patches of sweet potatoes are sometimes planted after maize has been harvested.

Cropping System

Land is prepared for planting in March and April by cutting weed growth that has occurred since the last cropping season. No burning has been used for the past five years. Fire is only used when fallow land is initially cleared.Plants are seeded in rows about 0.5 m apart. Holes are made with a stick at 1 m intervals. Rows are staggered to maximize the space between plants. Maize (2-3 seeds) and sorghum (10-15 seeds) are placed in the same hole. The brothers admit that they know that separate holes for maize and sorghum is more productive but say they prefer the one hole method as it is easier.

A mixture of grasses, broadleaf plants, and climbing vines are listed as the worst weed problems. Weeding occurs once, four weeks after planting, for corn and again in August for the sorghum. The herbicide 2,4-D is used during the first weeding. Twelve pounds of the herbicide is applied to one manzana. A backpack sprayer supplied by LUPE is used to apply the herbicide.

Significant insect pests were described as Langosta (fall army worm), Cogollero (stem borer) and Ciego (a white grub). No insecticides are use for insect control.

Once the maize crop has reached physiological maturity, the stalks are cut directly

above the ears to facilitate grain drying. The ears are brought to the house where the grained is removed from the ears and stored in containers or sacks. Harvesting is not conducted during a new moon as insect damage during storage is perceived to increase.

Conservation

The Sanchez brothers began cooperating with the NMRP in 1986. The payment of a food subsidy was the motivating factor for undertaking the construction of stone retention walls. The brothers feel that the productivity of the treated land has improved slightly over time. They attribute this primarily to the cessation of burning. Valerio Sanchez observed that the shape of the land was changing as the walls filled. He did not feel that significant soil loss was occurring on his unterraced land. Despite a large supply of rock, the brothers have no plans to build more walls as the feeling is that the labor requirements for construction are too great for their resources.

IV. Emigdio Casco, Texiguat

Ownership and size

The Emigdio Casco farm is located near Texiguat in the Texiguat watershed at an altitude of 780 m. The farm is comprised of 36 manzanas (25.2 ha). Mr. Casco obtained 8 manzanas from his parents and purchased the additional 28 manzanas over a period of years. The farm supports nine people, two adults and seven children. Off-farm income is obtained through Senora Casco who is employed as a primary school teacher. Two horses, twelve cows, and ten to twenty chickens comprise the farm livestock population.

Soil

The soils on the Casco farm have formed from adesite rock. These are young, shallow soils which are susceptible to erosion. These soils have a high level of chemical fertility. The soil test plot soil was classified as a Lithic Ustorthent. A soil profile from the test plot is presented below. Similar profiles observed on a nearby forested slope showed a mean depth to bedrock of 50 cm.

Horizon	Depth (cm)	Clay (%)	pH
A_p	0 - 15	25	6.2
A	15 - 35	25	6.2
R	35 +		

A few areas of the Casco farm have soils which have developed from granitic rock. These soils have very low fertility due to low base status. The decline in crop productivity was very evident on the test plot field where erosion of the basaltic derived soil is exposing the less fertile grantic soil.

Agricultural System

The land within the Casco farm has been managed under two agricultural systems. Due to high soil fertility, some fields have been in permanent cultivation for the past 25 years. On other, less fertile land, shifting cultivation was used to maintain fertility. At

present, Mr. Casco has shifted all his fields to permanent cultivation. The remaining fallow land is gradually being cleared and converted to pasture for cattle. Mr. Casco is completing this conversion by allowing some of his farm workers to clear a parcel and plant corn for one year. The next year the parcel is planted to grass.

The farm is divided into 3 distinct management units. Nine manzanas (6.3 ha.) is reserved as forest which supplies building materials and fuelwood. Seventeen manzanas (11.9 ha.) are bushland/pasture. The remaining ten manzanas (7 ha.) are divided into ten fields and under permanent cultivation.

Of the ten fields under permanent cultivation, three fields of one manzana each were plated to maize, three fields of one manzanza each were planted to maize and beans, and one manzana was seeded to maize, beans, and sorghum. Additionally, one manzana was seeded to sorghum, 1.5 manzanas were planted to watermelon and 0,5 manzanas were planted with sorghum for forage production.

Maize or maize and bean crops were planted during the primera and also the postrera growing seasons. Sorghum (Maicillo criollo) planted during the primera season was harvested in late December or early January. Sorghum for forage is planted in September or October, is harvested before seed is produced, and is fed to the cattle during the dry season. All maize and sorghum residue is removed from the fields to be fed to cattle. Whole bean plants are uprooted and removed to a central location for threshing. After threshing, the residue is scattered unevenly over portions of the field. The removal of significant amounts of residue results in a reduced mulch cover and greater exposure of the soil surface to raindrop impact.

Cropping System

Land preparation for planting takes place during late March and April. The soil is prepared by plowing along the slope contour with a hired oxen team. In 1991, no plowing was done as an early arrival of spring rains required that planting be undertaken before an oxen team was available for hire.

Planting for the entire farm is usually completed in three days by a crew of 20 - 25 men hired at a rate of 5 limpiras per day. A row spacing of one meter is used for all crops. For a bean - maize intercropping system plants are spaced within the row at 20 cm intervals. Two bean hills are planted between every pair of maize hills within the row. The beans are not planted until the corn is beginning to emerge. Seeding rates for bean and maize are two and three seeds respectively per hill. When sorghum is added to the maize - bean system it is planted in the same hole (8 - 10 seeds) as the maize. Sorghum planted alone is seeded at inter-row spacings of 80 cm to 1 m and intra-row spacings of 20 cm. No fertilizer is applied.

Langosta (Fall army worm) is considered the worst insect problem. Cogollero (corn stem borer) is also a significant pest. An insecticide, Linate was used for control. Bird predation on grain was also considered a problem in sorghum fields.

The only weeding of the primera season was carried out by hired labor during the middle of July, about 7 - 8 weeks after planting. Mr. Casco listed broadleaf weeds as his most serious problem.

Beans were harvested during the third week of July and immediately sold. Maize was harvested during the middle of August. Harvesting during a new moon is not undertaken as it is believed that problems with storage insects will be greater. Ears were transported by horseback to the family's house. The largest ears were selected to be saved for seed stock. The remaining ears were shelled and the grain stored in steel 55 gallon drums. Labor was hired for harvesting. Mr Casco estimated that 16 man-days are required for harvesting beans, 14 man-days for maize, and 8 man-days for sorghum. No harvesting of melons was conducted as the entire crop had been lost to drought.

Soil Conservation

Mr Casco began construction of stone retention walls in 1983 after talking to extensionists from the NRMP. He has constructed 1400 m of walls at a hired labor cost of approximately 2500 limpiras. He received no subsidies for construction. He plans to

install soil conservation structures on all of his cropland but plans to construct hillside ditches instead of stone walls. He feels that ditches are more cost effective and can be constructed on soils low in rock material. Mr. Casco firmly believes that terraces increase productivity but nevertheless insists that his land does not have a problem with soil erosion. He states that limited water is his most serious constraint to increasing production.

APPENDIX B

SOIL TEXTURE

TEXIGUAT	TEXTURE	% SAND	%SILT	% CLAY
1AU-15	CL	44	28	27
1AM-15	SCL	47	28	26
1AL-15	SCL	51	31	19
1AU-30	CL	40	30	30
1AM-30	CL	44	26	30
1AL-30	SCL	53	28	20
1BU-15	L	47	36	17
1BM-15	L	43	36	21
1BL-15	CL	44	30	26
1BU-30	CL	42	30	28
1BM-30	L	53	32	15
1BL-30	CL	42	30	28
2AU-15	SCL	47	29	25
2AM-15	CL	42	32	26
2AL-15	SCL	49	29	23
2AU-30	SCL	47	28	26
2AM-30	CL	42	30	28
2AL-30	SCL	50	28	21
2BU-15	CL	44	30	26
2BM-15	L	49	34	17
2BL-15	SCL	47	29	25
2BU-30	SCL	49	28	24
2BM-30	CL	43	29	28
2BL-30	SCL	51	28	22

Replications: 1,2
Treatments: A = Terraced B = Unterraced
Terrace transects: U = Upper M = Middle L = Lower

SOIL TEXTURE

NAMASIGUE 1

	TEXTURE	% SAND	% SILT	% CLAY
1AU-15	CL	37	46	17
1AM-15	C	45	16	39
1AL-15	L	42	36	22
1AU-30	CL	40	30	30
1AM-30	CL	43	30	27
1AL-30	CL	38	36	26
1BU-15	CL	34	39	27
1BM-15	CL	43	31	26
1BL-15	CL	36	36	27
1BU-30	CL	32	34	34
1BM-30	CL	32	34	33
1BL-30	CL	28	36	35
2AU-15	CL	36	39	26
2AM-15	CL	35	36	29
2AL-15	CL	38	35	27
2AU-30	CL	32	39	30
2AM-30	CL	29	39	32
2AL-30	CL	36	34	30
2BU-15	CL	43	31	26
2BM-15	CL	42	30	27
2BL-15	CL	40	33	26
2BU-30	CL	36	34	30
2BM-30	CL	34	34	31
2BL-30	CL	36	32	31

Replications: 1,2
Treatments: A = Terraced B = Unterraced
Terrace transects: U = Upper M = Middle L = Lower

SOIL TEXTURE

OROCUINA	TEXTURE	% SAND	% SILT	% CLAY
1AU-15	SCL	59	20	21
1AM-15	SCL	48	28	23
1AL-15	L	44	39	17
1AU-30	C	24	28	48
1AM-30	CL	36	26	38
1AL-30	CL	32	32	36
1BU-15	CL	44	30	26
1BM-15	CL	42	30	27
1BL-15	SCL	61	21	18
1BU-30	SCL	57	25	18
1BM-30	CL	40	29	31
1BL-30	C	33	28	40
2AU-15	CL	36	36	27
2AM-15	CL	41	34	25
2AL-15	C	51	32	18
2AU-30	CL	38	28	33
2AM-30	CL	36	29	35
2AL-30	CL	36	26	38
2BU-15	CL	42	31	26
2BM-15	CL	40	30	29
2BL-15	SCL	57	28	15
2BU-30	CL	36	29	35
2BM-30	CL	34	29	37
2BL-30	SCL	49	29	22

Replications: 1,2
Treatments: A = Terraced B = Unterraced
Terrace transects: U = Upper M = Middle L = Lower

Namasigue 2

SOIL TEXTURE

	TEXTURE	% SAND	% SILT	% CLAY
1AU-15	SCL	53	28	19
1AM-15	CL	40	32	28
1AL-15	CL	38	34	28
1AU-30	CL	32	32	36
1AM-30	C	30	30	40
1AL-30	CL	32	34	34
1BU-15	CL	40	34	26
1BM-15	CL	36	36	28
1BL-15	SCL	57	24	20
1BU-30	SCL	51	26	23
1BM-30	CL	42	28	30
1BL-30	CL	38	30	31
2AU-15	CL	34	34	32
2AM-15	CL	38	34	28
2AL-15	CL	36	34	30
2AU-30	C	26	30	44
2AM-30	CL	32	34	34
2AL-30	CL	38	30	32
2BU-15	CL	34	34	32
2BM-15	CL	40	34	26
2BL-15	CL	36	38	26
2BU-30	CL	42	32	26
2BM-30	CL	34	32	34
2BL-30	CL	32	32	36

Replications: 1,2
Treatments: A = Terraced B = Unterraced
Terrace transects: U = Upper M = Middle L = Lower

APPENDIX C

RAINFALL - 1991

TEXIGUAT

MONTH	1991	Mean†	Maximum	Minimum	Median
APRIL	9	24	143	0	16
MAY	167	182	492	5	137
JUNE	170	134	592	12	109
JULY	8	63	149	5	43
AUGUST	18	76	250	2	67
SEPT	279	162	446	19	173
OCTOBER	133	117	381	5	83

† Mean, maximum, minimum, and median based on 21 years of data.

NAMASIGUE 1,2

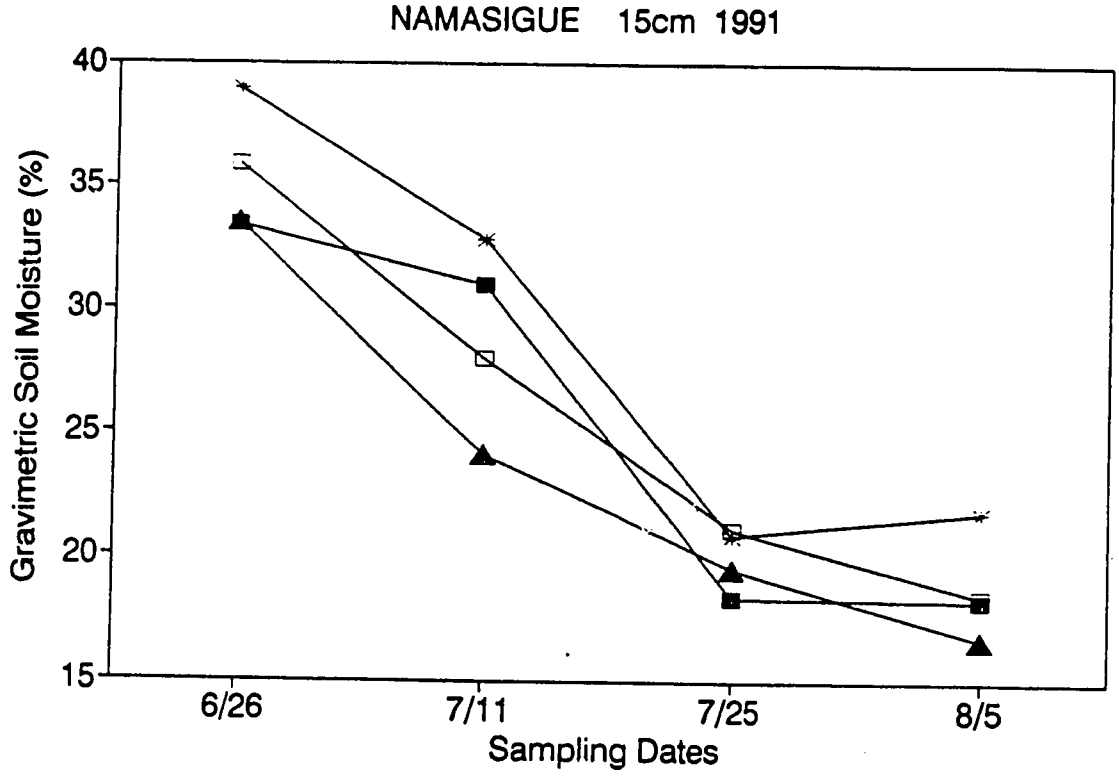
MONTH	Total 1991
APRIL	0
MAY	50
JUNE	134
JULY	19
AUGUST	15

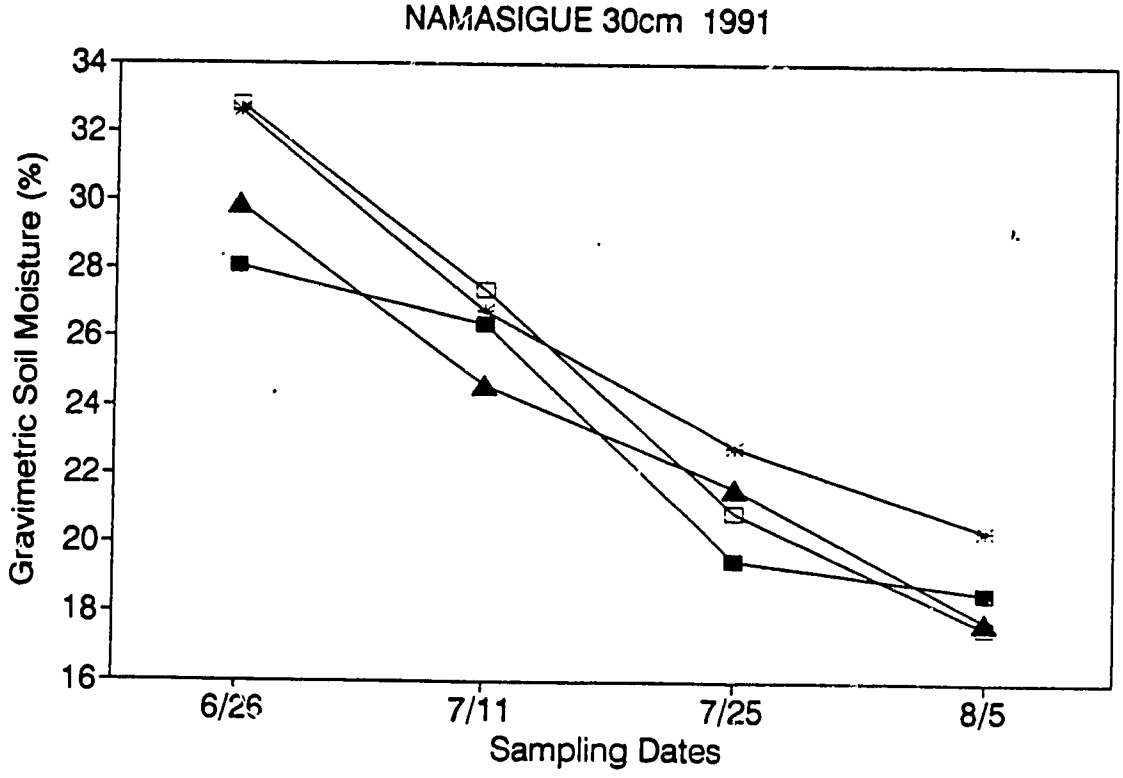
OROCUINA

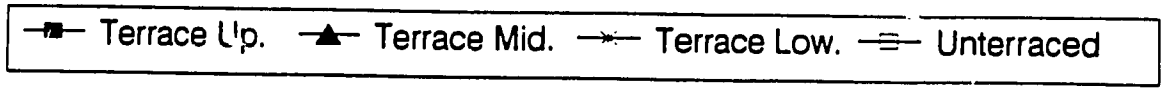
MONTH	Total 1991	Mean
APRIL	0	Na
MAY	9	217
JUNE	10	249
JULY	3	74
AUGUST	15	4

APPENDIX D

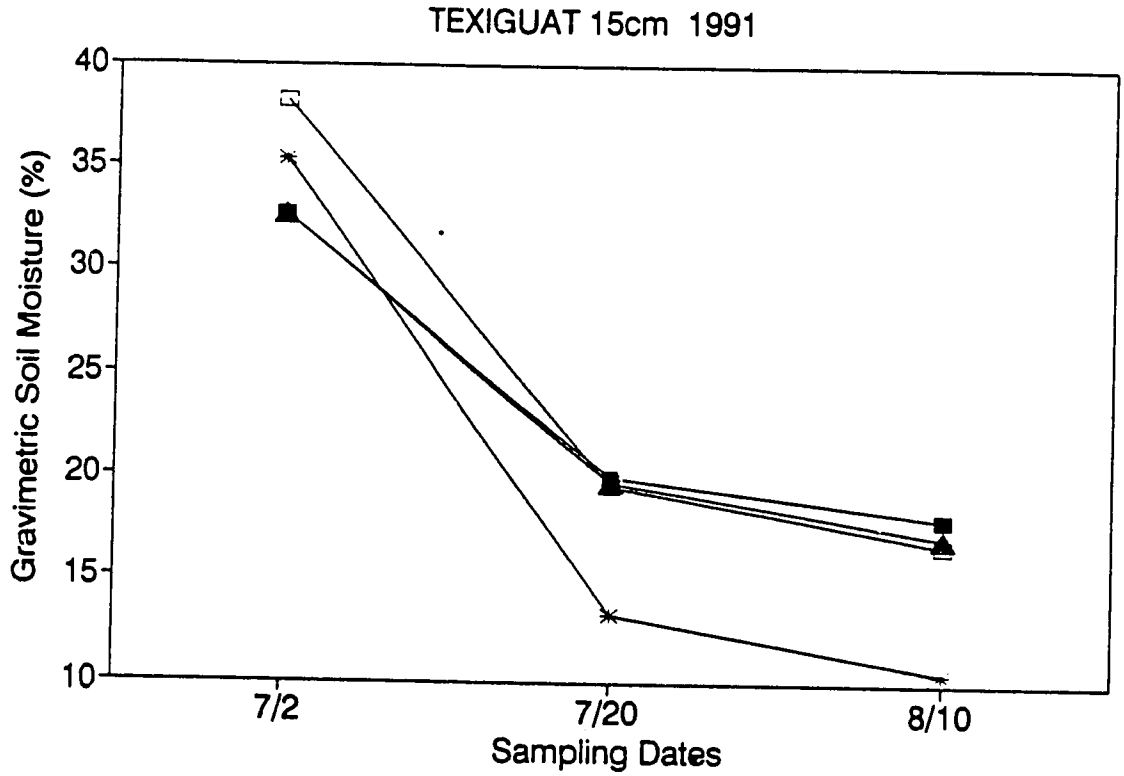
Gravimetric Soil Moisture - Namasigue 1
Primera Season

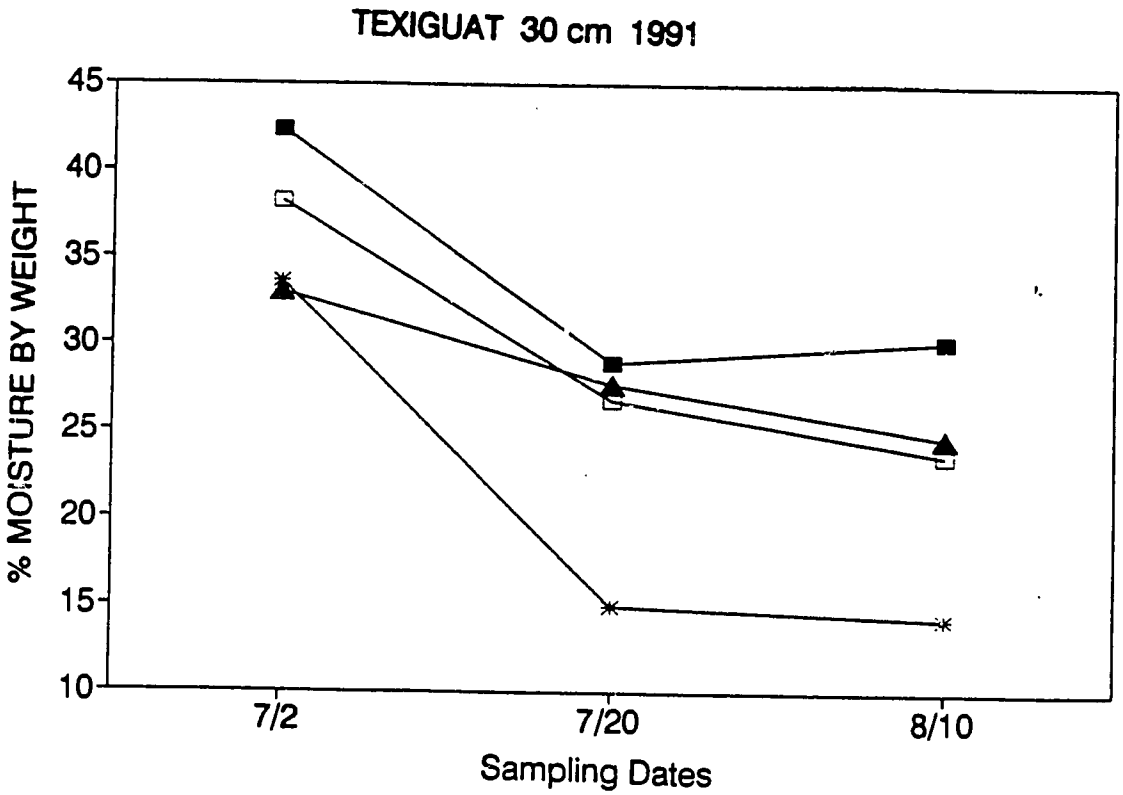






Gravimetric Soil Moisture - Texiguat
Primera Season





Terrace Up. Terrace Mid. Terrace Low. Unterraced

APPENDIX E

Crop yield data
Postrera season

Effect of terracing on postrera crop yields.

Location	Vegetative Production	Terrace	Unterraced
		kg/ha	
Namasigue 1	Grain	No Crop	
	Stover		
	Total Biomass		
Namasigue 2	Grain - Sorghum	1864	1734
	Stover	6823	3829
	Total Biomass	8687	5563
Orocuina	Grain	2500	1530
	Stover	----	----
	Total Biomass		
Texiguat	Grain (Maize)	1314	878
	Grain (Beans)	----	----
	Stover (Maize)	1014	730
	Stover (Beans)	----	----
	Total Biomass	4635	1941