Alternatives to Bench Terraces on the Hillsides of Jamaica: I. Soil Losses[1]

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ABSTRACT

A study aimed at determining appropriate soil conservation measures other than bench terracing was conducted in an Ultisol in Jamaica for 2 crop years. Mean annual soil losses for 2 consecutive years, from check plots planted to yellow yams (*Dioscorea* sp.) on individual hills without a hillside ditch, amounted to 192 t/ha/yr. Hillside ditches and intercropping yam with Irish potato decreased soil losses by 35%. A further reduction was achieved by intercropping yam with Irish potato on continuous contour mounds interrupted by a hillside ditch. The best erosion control was attained on yam plots intercropped with Irish potato on continuous contour mounds with a grass buffer strip.

INTRODUCTION

Jamaica is the third largest of the Caribbean Islands. It lies between lat. 17°45′ and 18°30′ N. and long. 76°15′ and 78°15′ W. The land area covers about 11,400 km^2 (4,244 square miles) with a maximum transverse length of 146 miles and a width varying from 22 to 51 miles (35–81 km).

Land distribution by slope classes shows that about 38% of the area is relatively flat to undulating (0° to 10°); 32% of moderately steep slope (10° to 30°); and 30% of steep slope (over 30°).

The relatively high population density of Jamaica (190/km^2) cultivating small farms on steep hillsides to produce most of the foodstuffs for local consumption has caused serious soil erosion. In addition, the traditional practices followed by farmers who produce yam, one of the staple foods in the Jamaican diet, also increase erosion.

Hillside farming on steep slopes without proper soil conservation measures is probably the most serious constraint to high productivity and sustained soil fertility, as well as watershed conservation in Jamaica.

Food crop production is primarily based on a shifting cultivation type of farming. For more than 3 decades the major soil conservation practices applied on the cultivated hilly watersheds in Jamaica have been contour trenches and barriers. Most of these structures have been inadequately laid out, poorly implemented and maintained, and of an ephemeral

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nature. As a result, they have deteriorated to the extent that very little lasting benefits have accrued.

Soil erosion and sedimentation are two of the most important factors confronting those who are concerned with crop production as well as water resource development in Jamaica. There are, however, few data concerning the rates of erosion and sedimentation.

This paper describes the results of the runoff plot studies as affected by soil conservation and cropping system differentials. Data on soil losses measured for two consecutive years are discussed. Data on crop yields will be given in the second paper in this series.

MATERIALS AND METHODS

SITE

The Olive River Demonstration Centre (consisting of 1.5 ha) is located in South Trelawny at about 820 m above sea level and at a distance of about 10 km northeast of Christiana. The region is typical of traditional hillside farming areas of Jamaica where yam (*Dioscorea* sp.) is the main crop. The land slopes towards the northwest with no distinct natural drainage system over the entire area. About 65% of the land is gently sloping land (under 15°) and 35% is moderately to steeply sloped land (15° to 25°).

The rainfall pattern at the experimental site at Olive River is similar to that of the average for the entire Island; total yearly rainfall is 2,261 mm (89 inches) as computed for the 10-year period 1969–1978. Driest months are December through March and the wettest are April to June and August to October. The soil is an Ultisol with a dark brown clay with good structure to a depth of 10 cm over a yellowish red clay with weak structure which extends to a depth of about 30 cm. Internal drainage seems to be poor. The soil is very acid (pH 4.8), low in levels of available N, P, Mg, Ca, Zn and Cu, and medium in levels of available K and Mn.

The site where the runoff experiment plots are located has lain fallow for several years. Prior to the construction of the runoff plots it was necessary to remove the topsoil in places in order to obtain a uniform gradient of 20°. However, this topsoil material was replaced prior to cropping.

MEASUREMENT OF SOIL AND WATER LOSSES

The size of the runoff plot was determined in part by the morphology and growth characteristics of yam, the principal test crop. In addition, the size, as well as number of plots, were limited by the actual relief of the plot size. On the basis of the above considerations the size of the runoff plot was fixed at 2.7 m wide and 15.8 m long along a 20° slope or 2.7 m × 14.8 m horizontally, for a runoff area of 40 m^2 (0.004 ha).

Each plot was delineated by concrete block boundary walls about 35 cm high from the soil surface and 15 cm wide. To divert rainfall water from the walls away from the test plots, a U-shaped crest was mounted on the top of each wall. Each boundary wall was reinforced by means of a concrete side pavement 20 cm wide and 11 cm deep. These side-pavements (one/plot) served as a foot path to service the plot and crops, and to prevent scouring erosion along the boundary wall.

The runoff collection troughs (Fig. 1, 2) are positioned across the lower end of each plot and serve as a weir for sediment runoff, most of which

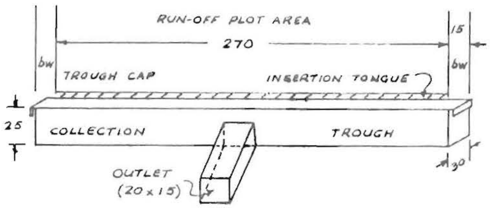

FIG. 1.—Front view of collection trough (unit: cm).

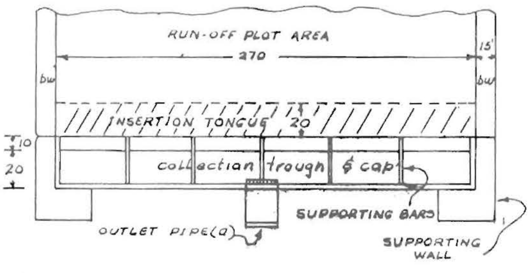

FIG. 2.—Top view of collection trough (unit: cm).

will finally enter a set of two sediment/suspension tanks.

The trough is made of galvanized malleable sheet. The trough is connected to the plot-soil by means of tongues about 20 cm long. The dimensions of the trough are 270 cm × 30 cm × 25 cm (depth). To prevent off-plot debris as well as off-plot rain water from entering the trough it was fitted with a cover of galvanized sheet.

Runoff materials from the trough are conveyed to sediment tanks by means of a rectangular conduit (100 cm × 20 cm × 15 cm) made of galvanized sheet (Fig. 3, 4). Two 55-gallon capacity metal drums were installed for each runoff plot for the collection of runoff soil-water material. These tanks designated A and B are referred to as sediment tank (A) and suspension tank (B). The major function of tank A is to retain heavier soil particles with the soil suspension passing to tank B.

A standard rain gauge was installed within the runoff plot area and daily rainfall measured at 8:00 every morning.

Following each period of a "very heavy soil run-off" resulting from heavy rainfall, or after several periods of rainfall, the volume and wet weight of the soil sediment in the tanks and troughs were measured and recorded. For determination of soil loss, the following procedure was

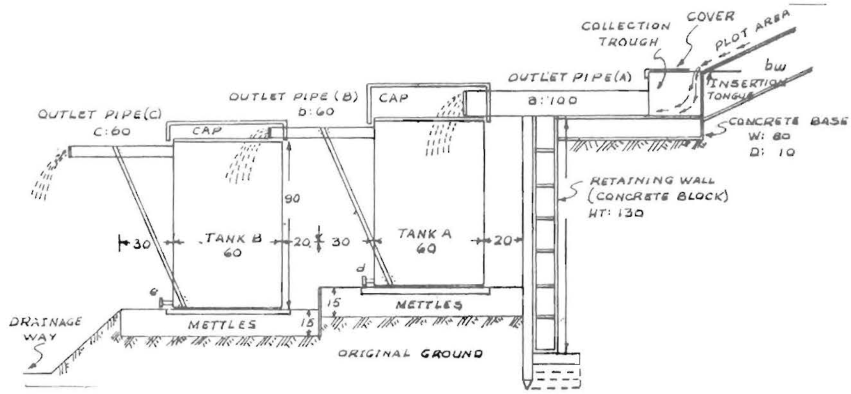

FIG. 3.—Side view of tank A & B, outlet pipe a, b, c, d, e, trough, retaining wall, and concrete base (unit: cm).

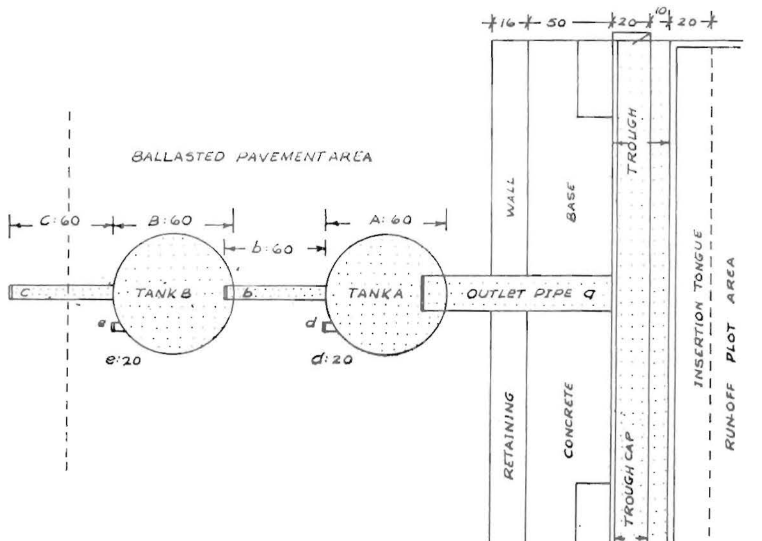

FIG. 4.—Top-view of tank A & B, outlet a, b, c, d, e, trough, retaining wall and concrete base (unit: cm).

used: weighing of the wet soil sediment contained in both troughs and tanks; three samples (aliquots) were collected from the soil sediment for moisture content determination. The wet sediment samples were oven-dried at 105° C for 72 hours after which time final weight was determined; the moisture percentage of the sediment samples was then calculated. The moisture content of the soil-sediment/suspension within the trough and tank was determined by averaging the three values. A simple procedure for measurement and calculation of soil-loss was then made.

SOIL CONSERVATION PRACTICES

Arrangement of the soil conservation practices and cropping system is shown in the following tabulation:[3]

I.	Individual hills (check)	Yellow yam as a monocrop
II.	Individual hills with a hillside ditch	Yellow yam intercropped with Irish potato followed by radish and peanut
III.	Contour mounds with a hillside ditch	Yellow yam intercropped with Irish potato followed by radish and peanut
IV.	Contour mounds with a grass buffer strip	Yellow yam intercropped with Irish potato followed by radish and peanut

RESULTS AND DISCUSSION

Table 1 shows rainfall and number of rainy days during the two experimental periods.

During the first year (April 1980–February 1981), a total of 1,295 mm of rainfall was recorded in 89 rainy days. For the second year (March 1981–January 1982), a total of 1,926 mm of rainfall in 122 days was recorded. During the second year there was about 49% rainfall increase over the first year. This increased rainfall resulted in more soil erosion from the runoff plots.

During the first year, the highest total rainfall (332 mm) was recorded in May 1980, with 17 rainy days, and the lowest (35.8 mm), in February 1981, with only four rainy days. In the second year, the highest rainfall was recorded in October 1981, with 336.5 mm in 20 rainy days and the lowest (27.6 mm) in December with only 4 rainy days. Rainfall was uniformly distributed during the second year, but it was irregular during the first year. Table 2 shows the heavier 10 daily-rainfall records during the 2 years.

[3] In the second year the cropping patterns were reduced to a combination of yellow yam and Irish potatoes.

Table 3 presents data on soil losses for each treatment at given time periods. In all cases, heavier losses were measured from the control plots. Table 4 summarizes the data on soil losses by treatments for each experimental year.

During the first year, soil losses by treatments were significantly different (0.05 probability level). Heavier losses (182.2 t/ha) were measured in the check plots as compared with those of other treatments. Losses in treatment II averaged 105.3 t/ha and were significantly smaller than those recorded from the check plots. There were no other statistical differences among treatments even though differences as high as 62.3 t/ha were recorded (table 4).

TABLE 1.—*Monthly rainfall and number of rainy days at Olive River, 1980–1982*

First Year				Second Year			
Year	Month	Rainfall	Rainy days	Year	Month	Rainfall	Rainy days
		mm	no.			mm	no.
1980	May	332.0	17	1981	March	100.0	8
	June	89.2	4		April	173.1	9
	July	136.9	10		May	219.1	11
	August	272.7	8		June	165.4	16
	September	67.9	10		July	226.4	13
	October	106.0	10		August	220.1	16
	November	61.1	9		September	258.6	11
	December	144.5	9		October	336.5	20
1981	January	43.2	7		November	171.2	10
	February	35.8	4		December	27.6	4
	March	5.8	1	1982	January	27.4	4
	Total	1,295.1	89			1,926.3	122

TABLE 2.—*Heavier 10 daily rainfall records at Olive River during the experimental years*

First experimental year		Second experimental year	
Date	Rainfall	Date	Rainfall
	mm		mm
August 5, 1980	116.2	April 28, 1981	80.0
August 6, 1980	100.4	August 27, 1981	78.0
May 25, 1980	53.0	October 14, 1981	77.8
December 20, 1980	51.6	October 14, 1981	73.8
May 1, 1980	47.3	May 19, 1981	72.6
July 1, 1980	47.0	July 1, 1981	63.0
July 9, 1980	42.6	September 27, 1981	53.7
December 22, 1980	39.6	September 26, 1981	53.6
May 9, 1980	37.4	November 6, 1981	53.0
May 29, 1980	37.2	December 21, 1981	47.0

TABLE 3.—*Dates of soil sediment collection, rainfall and soil losses at Olive River during 1980–1982*

Collection period		Rainfall		Mean soil losses by treatment			
Period	Length of interval	Rainy days	Rainfall during interval	T-I	T-II	T-III	T-IV
	Days	no	mm	kg			
		First experimental year					
1980							
April 26–May 8	13	5	87.9	77.23	54.49	22.92	24.10
May 9–May 20	12	6	92.8	174.93	93.64	42.54	33.98
May 21–May 27	7	3	83.3	97.14	35.71	10.05	8.12
May 28–June 10	14	7	157.2	108.44	27.04	5.65	3.59
June 11–July 4	24	2	55.0	38.15	2.79	0.86	0.91
July 5–July 22	18	8	81.9	93.01	74.88	30.88	36.23
July 23–Aug. 12	21	3	229.1	83.50	72.21	52.48	32.68
Aug. 13–Sept. 9	28	8	66.4	17.21	17.01	9.94	7.20
Sept. 10–Oct. 7	28	10	66.3	27.35	21.30	11.40	10.59
Oct. 8–Dec.10	64	18	154.5	24.79	13.99	8.49	8.47
1981							
Dec. 11–March 3	83	19	220.7	4.93	8.04	5.78	6.21
Total	312	89	1,295.1	728.65	421.07	200.96	172.08
		Second experimental year					
1981							
March 4–March 13	10	3	70.8	59.78	38.34	22.37	11.03
March 14–April 22	40	10	79.7	24.68	23.77	12.72	6.28
April 23–April 28	6	2	100.0	153.63	136.55	65.71	68.58
April 29–May 11	13	7	86.6	41.47	35.91	23.07	20.76
May 12–May 27	16	6	156.0	72.19	48.45	24.44	31.84
May 28–June 30	34	16	165.4	70.81	22.02	18.27	18.81
July 1–July 20	20	8	204.2	158.82	101.24	66.42	69.69
July 21–Aug. 25	36	18	154.2	20.45	19.29	15.54	15.39
Aug. 26–Sept. 16	22	8	145.0	36.38	25.67	17.05	15.22
Sept. 17–Oct. 6	20	11	254.2	53.48	46.93	27.26	28.52
Oct. 7–Oct. 21	15	11	151.9	39.01	28.65	21.59	28.07
Oct. 22–Nov. 11	21	9	262.3	73.51	53.23	49.44	47.36
Nov. 12–Dec. 9	28	6	44.5	3.74	3.31	3.09	3.24
Dec. 10–Jan. 11	33	7	51.5	0.69	0.65	0.56	0.64
1982							
Total	314	122	1,926.3	808.62	584.49	367.53	365.42

Soil losses for the second year were very similar to those of the previous year (table 4). Highly significant differences (0.01 probability level) were detected among treatments. More soil losses were recorded from T-I (202.2 t/ha); the amount lost was significantly higher than that of any of the other three treatments. As in the first year, T-II had the second largest soil loss (146.1 t/ha), but differences between losses in this treatment and losses in T-III and T-IV were significant. No differences were found between treatments III and IV.

A combined analysis (Pooled AOV) for the 2 years revealed a highly significant difference between years and treatments (average over years). There was no interaction between treatment X year, which indicates that treatments performed in the same way during the two years regardless of the highly significant differences between years. The data indicate that there were differences among the four soil conservation alternatives and that they are consistent in performance during both years. T-III and T-IV (contour mounds with a hillside ditch and contour mounds with a grass buffer strip, respectively) are significantly better as soil conservation practices than T-I (check) and T-II (individual hills with a hillside ditch).

TABLE 4.—*Soil loss measurements and evaluation for two experimental years, Olive River*

Treatment	Soil loss	Depth	Ratio to T-I
	t/ha	mm/yr	
	First experimental year		
T-I	182.2*[1]	12.4	100.0
T-II	105.3	7.2	57.8
T-III	50.2	3.4	27.6
T-IV	43.0	2.9	23.4
	Second experimental year		
T-I	202.2*[1]	13.8	100.0
T-II	146.1	9.9	72.3
T-III	91.9	6.3	45.4
T-IV	91.4	6.2	45.2

[1] LSD: first year—71.7; second year—40.7.

Annual soil loss could be estimated as about 13.1 mm/year from treatment I; 8.6 mm/year from treatment II; 4.8 mm/year from treatment III; and 4.6 mm/year from treatment IV.

In other words, under the conditions of the experiment one ha—15 cm furrow-slice of soil can be lost in about 12 years using the traditional yam cultivation method. However, intercropping yams with short cycle crops such as Irish potato and radish on the individual hills interrupted by hillside ditches at appropriate vertical intervals, can reduce soil losses to the extent where about 18 years would be required to experience the loss of the upper 15 cm soil layer. Intercropping yams with Irish potato and radish on the continuous contour mounds with a hillside ditch or a grass buffering strip at fixed intervals, can reduce soil losses to the extent where about 30 to 32 years would be required for the loss of the upper 15 cm soil layer.

In the first 2 to 3 months after planting, great differences in soil losses between the control plot and other intercropped plots were observed. In practice, the control plot could be considered as not having any crop canopy whatsoever since it was cropped to yams alone, a condition which initiates sprouting during the first 8 weeks followed by another 8 weeks of rapid shoot elongation and leaf development. In other runoff plots, although the yam crop was developing at the same rate as in the check plot, at 45 days the Irish potato crop had germinated and established a good crop cover, and by 50 days floral initiation had been completed. As the Irish potato crop developed and attained full crop cover, it was evident that, in addition to the physical soil conservation measures adopted, crop cover had a profound effect on the quantity of soil loss down from the 20° hillside plot. Furthermore, when the effects of the intercrop (i.e. Irish potato) are separated from the main treatment effects (i.e. traditional hills vs. contour mounds or traditional hills with hillside ditch), an 80 to 88% reduction in soil loss can be achieved, even during the early stages.

Even though considerable differences were detected with a very simple and restricted design (RCB with two replications and four treatments), trials should be continued since 2 years data for a soil conservation experiment are usually considered inadequate. Meanwhile, serious considerations should be given to the fact that either continuous contour mounds with a hillside ditch or a grass buffer strip are far more efficient in delaying the soil loss in hillside agriculture than the traditional method. In addition, these two soil conservation practices cost considerably less than bench terraces, and provide equal or better crop production and soil conservation. For example, a hand-made bench terrace on 20° slope land will cost approximately J$5,355 per hectare while a hillside ditch will cost only J$714 per hectare and a grass buffer strip no more than J$300 per hectare. Studies conducted at the Smithfield Demonstration Area in Hanover[4] indicated that soil losses ranged from 7t/ha/yr on bench terraces to 11 t/ha/yr with hillside ditches and contour mounds. Two-year data from Olive River experiments show no significant differences in soil loss between hillside ditches and contour mounds, and grass buffer strips and contour mounds.

RESUMEN

En las parcelas testigo de una evaluación de diversas prácticas de conservación de suelos en Jamaica, sembradas de ñame (*Dioscorea* sp. L.) en montículos individuales sin zanjas de ladera, las pérdidas de suelo

[4] 1980 estimates made by the Soil Conservation Department, Ministry of Agriculture, Jamaica.

fueron de 192 Tm/ha/año. Con la construcción de zanjas de ladera e intercalando la siembra de ñame con la de papa, se redujeron las pérdidas de suelo en 35%. Se logró una mayor reducción cuando se intercaló la papa con el ñame sembrado en montículos continuos siguiendo las curvas de nivel y separados por zanjas de ladera. La mayor reducción en pérdidas de suelo se logró en las parcelas donde se intercaló la siembra de ñame con la de papas en montículos continuos y con una franja amortiguadora de yerbas.