CROP PRODUCTION ON HILLSIDES USING NON-BENCH TERRACING ALTERNATIVE MEASURES FOR SOIL CONSERVATION

First Year's Results of the Olive River Soil Conservation Studies

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Ministry of Agriculture
and
IICA in Jamaica

1981

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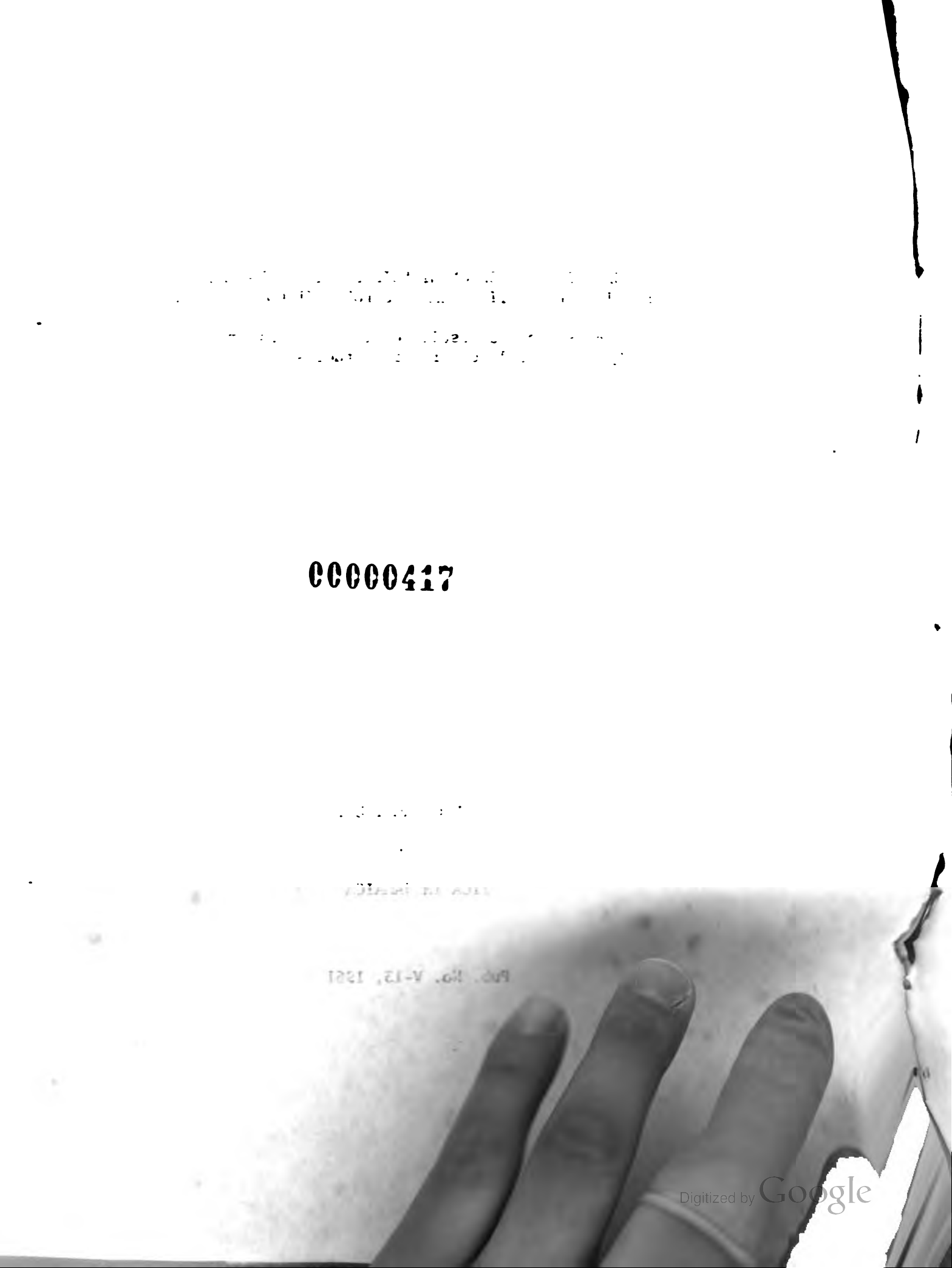

FOREWORD

Over the years, although soil erosion has been the subject of much debate, actions taken to provide appropriate soil conservation measures have not been pursued with any degree of continuity until during the last decade.

Various measures have been tried, adopted, discarded, re-examined and tried again. Information is available on the successes, failures, technological and other inputs related to soil conservation. The high density of farmers on the very erodible hillside lands used by 80% of Jamaican farmers, and the scarcity of land for agricultural production, make it necessary to search for the highest production at the lowest cost, which at the same time preserves this non-renewable asset - land.

This work is a spin-off of the Government of Jamaica/IICA Allsides Project where appropriate systems of production were tested on newly terraced lands. It was evident, however, that bench terracing is a high cost measure of conserving land. Government of Jamaica/IICA in their desire to obtain complete information on the subject of soil conservation, initiated the Olive River Experimental Station for testing selected multiple cropping systems of production on alternative systems using soil conservation measures other than bench terracing, and emphasizing the results of the following three variables - production, soil loss, and soil conservation costs.

The data presented should continue to be collected and analyzed for at least five more years so that the Ministry of Agriculture will have a sound basis for undertaking policy decisions.

We wish to congratulate Dr. Bo-Myeong Woo from the Republic of Korea (South), Dr. Abdul Wahab and Mr. Joseph Dehaney for the excellent work they have undertaken in bringing this project to its present stage. This document is an account of the project to date.

Dr. Percy Aitken-Soux
Director, IICA/Jamaica

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CROP PRODUCTION ON HILLSIDES USING NON-BENCH TERRACING ALTERNATIVE MEASURES FOR SOIL CONSERVATION

First year's results of the Olive River soil conservation studies[1/]

Bo-Myeong Woo, Abdul H. Wahab, Joseph Dehaney[2/]

ABSTRACT

A long term study aimed at determining appropriate soil conservation measures, other than bench terracing, has been initiated by the Ministry of Agriculture and IICA in Jamaica in 1979. In the first year, the experiment consisted of eight run-off plots representing four treatments replicated twice. A plot size was 40 m^2 (2.7 m wide and 15.8 m long) along the slope of 30°. During the trial period (April 1980 to March 1981) which represents one crop cycle for yellow yam, 1,300 mm of rain was received over 89 rainy days. During this time sampling of soil sediment was made eleven times for estimation of soil loss from the run-off plots.

Soil loss from the check plots (T-I), on which yams were grown on individual hills without a hillside ditch, amounted to 179 tons of oven-dry soil per hectare. However, by constructing a hillside ditch and intercropping yam with Irish potato and radish (T-II), soil loss decreased by 42% to 103 t/ha. A further reduction in soil loss was achieved by intercropping yam with Irish potato and radish on continuous contour mounds interrupted by a hillside ditch (T-III). This treatment resulted in a soil loss of 49 t/ha or 72% less than the check plot. Greatest reduction in soil loss was observed from plots of yam intercropped with Irish potato and radish on continuous contour mounds

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1/ Part of the studies entitled "Pilot Hillside Farming and Development Project" conducted jointly by the Ministry of Agriculture and IICA.

2/ Soil Conservation Specialist (Participated from Seoul National University, Korea) IICA/Jamaica, Agricultural Research Specialist IICA/Jamaica, and Soil Conservation Officer, Ministry of Agriculture, respectively.

T-I = Treatment No. 1

T-II = Treatment No. 2 etc.

[illegible] NON-TRENCH
[illegible] SOIL CONSERVATION

[illegible] results of the [illegible]
[illegible] studies[1]

[illegible][2]

[illegible]

A long term [illegible] soil [illegible] measures, [illegible] has been initiated by [illegible] Agriculture [illegible] in 1977. In the first year, the experiment consisted of eight run-off plots [illegible] four treatments replicated twice. Plot size was 40 m² ([illegible] and 12.5 m long) along the slope of 60%. [illegible]) which represents one crop cycle for yellow yam [illegible] was received over 86 rainy days. [illegible] this time [illegible] of soil [illegible] was made eleven times for [illegible] soil loss [illegible].

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1/ [illegible] the studies [illegible] Hillside Farming and Development Project [illegible]

2/ [illegible] University, [illegible] Agricultural Research [illegible]

T I = Treatment [illegible]
T II = Treatment [illegible]

with a grass buffer strip (T-IV), in which soil loss amounted to 43 t/ha or 76% less than the check plot.

Marketable yam yields were highest for the check plot (29 t/ha) and treatment II (30 t/ha), and lowest for treatments III and IV plots (17 t/ha). Where yam was intercropped with Irish potato and radish, marketable potato yields ranged from 7 to 9 t/ha, whereas yields of marketable radish ranged from 700 to 900 kg/ha.

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INTRODUCTION

Most of Jamaica is comprised of sloping to steep lands. For example, only about 30% of the land area of approximately 1,000,000 hectares is relatively flat to undulating (0° - 10°), whereas about 53% is hilly to mountainous, with slopes ranging from 20° to over 30°.[7/]

The land area of about 11,290 square kilometres may be conveniently divided on the basis of physical characteristics into 33 principal watersheds. Because of the relatively high population density of Jamaica (190/km^2)and the fact that the small farms located on steep hillsides are used in producing most of the foodstuffs produced for local consumption, the hillsides of Jamaica have over the years been subjected to serious soil erosion. Militating against this serious loss of natural resource are the traditional practices followed by farmers who produce yam - one of the staples in the Jamaican diet. According to the traditional practices of yam-growing, the crop is planted on individual hills which are for the most part of the crop cycle exposed to the elements of the weather. This practice when done on a 17° slope results in the loss of 117 tons of oven-dry soil per hectare per year.[10/]

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.

The pattern of cultivation of the country's hilly watersheds is one of shifting cultivation, on a widespread basis for the production of food crops. For more than three decades the major soil conservation treatments applied on the cultivated slopes have been contour trenches and barriers. Most of these structures were inadequately laid out, poorly implemented and maintained, and of an ephemeral nature. As a result, they have deteriorated to the extent that very little lasting benefits have accrued.[12/]

In parts of the Olive River watershed, which is the subject of this report, land on slopes of over 25° is planted under clean cultivation. These slopes are characterized by shallow soils and are not recommended for intensive cultivation, unless properly managed. In order to protect cultivated slopes in hilly watersheds. two essentials are:

(i) to use the land according to or within its capability;

(ii) to adopt more permanent types of soil conservation measures such as bench terraces and their variants, together with an appropriate water disposal system to cater for periods of excessive run-off water.

Soil erosion and sedimentation are two of the most important factors confronting those who are concerned with crop production as well as water resources development in Jamaica. There is little data concerning the rates of erosion and sedimentation. These rates are influenced by factors such as land slopes, soil types, land use, and climate, and vary from place to place. It is only possible to discuss them peripherally in this presentation.

Today, soil erosion is almost universally recognized as a serious threat to man's well-being, if not to his existence, and this is demonstrated by the active support of governments to programmes of soil conservation. Although unknown 90 years ago, the science of soil conservation has grown and developed into one that is now receiving world-wide attention. For this reason, a brief discussion on the development of this discipline appears to be germane.

The first scientific investigation of soil erosion was carried out by the German soil scientist Wollny, between 1877 and 1895. Small plots were used to measure a wide range of effects, such as those of vegetation and surface mulches on the interception of rainfall and on the deterioration of soil structure, and the effects of soil type and slope on run-off and erosion. Apart from this pioneering work, the bulk of activities relating to erosion research has been centred mainly in the United States of America.[5/]

The first American experiments were established by the Forest Service in 1915 in Utah. They were followed by those of Miller in Missouri in 1917. Bennett organized a network of ten field experiment stations between 1928 and 1933, and this programme expanded to forty-four stations. Other pioneering work in this field was carried out in the 1930's by Baver, Borse, Woodburn, and Musgrave, which led to the first detailed study of natural rain by Laws in 1940. The first analysis pertaining to the mechanical action of rain drops on the soil was undertaken by Ellison in 1944. Later, analytical research was directed at more specific objectives by the setting up in 1954 of a national study, which used modern techniques of data analyses to correlate the results of all field experiments. As a result, the main features in the erosion process were identified and mathematically enumerated. This work ushered in the present phase of quantitative scientific investigations.5/

In Africa, Haylett started research work on soil erosion at the University of Pretoria in 1929, and established the first set of run-off plots. This was followed in 1933 by the work of Staples in Tanzania (Tanganyika). Today, a network of field stations is in operation in a dozen or more territories. A notable programme including both field experiments and detailed laboratory studies was carried out in Rhodesia at the Henderson Research Station.5/

In the West Indies, experiments on rates of soil erosion and measurements have been conducted in Puerto Rico, Trinidad and Tobago, by the University of the West Indies in 1973 and by the IICA/Barbados Office in 1978.1/ 2/ 3/

The Hermitage Water Reservoir was constructed in 1929, in Kingston, Jamaica, and was equivalent to a watershed of 3,400 acres (5.3 square miles). However, by 1963 it had lost 45% of its storage capacity or 210 million imperial gallons due to sedimentation. The rate of sedimentation is estimated by both the Harza Engineering Co. and Champion (1966) at four acre-feet per year per square mile. Hurricane Flora rains in October 1963 are reported to have caused massive sediment inflow to the reservoir, although the cover of the entire watershed is better than average.12/

In cultivated watersheds the rate of erosion is considerable. Champion (1966) estimated the soil loss from the Upper Yallahs Valley where about one-third of the land area is under cultivation at any time, at 40 tons per acre per year or fourteen (14) acre-feet per square mile per year.[12/]

A soil loss experiment on Wait-A-Bit clay loam (No. 95) conducted by Mitchell during 1962 - 1963 at James Hill, central Clarendon, indicated that a bare escarpment lost an everage of 1.4 inches annually. The method used was to place metal spikes in the ground.[12/]

Further work started in this direction in 1969 through the UNDP/FAO JAM 505 Project conducted in collaboration with the Soil Conservation Unit in the Ministry of Agriculture. A site with a slope of 17 degrees was selected at Cascade in the parish of Hanover, for studying soil loss and run-off by plots of yellow yams (Dioscorea cayenensis) which is the principal crop of that region. This project site is now known as the Smithfield Demonstration Centre.[10/]

The plots were treated with soil conservation measures as follows:

(i) check (or control);
(i) hillside ditch and individual basins;
(iii) hillside ditch and contour mounds; and
(iv) bench terraces.

After every run-off producing storm, measurements were made of the volume of soil lost and run-off water. Yam yields were recorded for each crop. After 43 months of observation the results obtained and analysed were as follows:

(a) The average soil loss from the check plots was 54 tons of oven-dry soil per acre per year whereas from the bench terraced plots it was 7 tons per acre per year. Among the various levels of conservation treatments, however, soil losses varied from 7 to 16 tons per acre per year.

(b) No significant difference was found in annual run-off among all the plots. The run-off percentage was approximately one-third of the annual rainfall in a cropping year.

(c) Continuous cultivation at check plots degraded and depleted the soil productivity to a great extent whereas on terraced plots the productivity was maintained and improved.

In 1977, the Government of Jamaica requested IICA's assistance in developing viable systems of production for newly terraced lands. Recognizing the high capital cost required to erect bench terraces, work began in 1980 to test the viability of farming systems (multiple-cropping) developed for terraced hillsides, on simpler and less costly soil conservation measures.[14/] After much searching it was possible to find a site at Olive River for undertaking this research.

The Olive River Soil Conservation Demonstration Centre is located within the Lowe River area of Trelawny. The Project is aimed at the establishment of demonstration plots for farming systems treated with soil conservation methods other than bench terracing.[14/] The treatments are, therefore, designed to suit the aims above, and are as follows:

(i) yam grown on individual hills using the clean cultivation method as practiced by farmers;

(ii) yam on individual hills using inter-cropping and the hillside ditch measure;

(iii) yam on contour mounds with inter-cropping and the hillside ditch measure; and

(iv) yam on contour mounds with inter-cropping and the grass buffer strip measure.

The soil at the Olive River Demonstration Centre is classified locally as the Wait-A-Bit clay (Map No. 95) and the slope of the run-off plots is 20°.

The size of a run-off plot is 2.7 metres wide by 15.8 metres along the slope making 40 square metres of rectangular run-off area which is 1/100th of an acre on 20° sloping land.

It took about five months starting from November 1979 to late March 1980, for installation and construction of the test plots.

This report serves to describe in detail the procedure for establishing the run-off plots from the design through the installation and construction stages. Also discussed is the first year's data on soil loss and crop production at the Olive River Centre.

2. CLIMATE AND SOILS

2.1 Climate

2.1.1 Rainfall

Mean annual rainfall in Jamaica over a 90 year period is approximately 1,978 mm (78 inches). Rainfall in Jamaica is heaviest in the north-east upland regions where over 5,080 mm (200 inches) of rain is recorded per year and lowest along the coastal strips extending from Bull Bay to Black River in the south, and the narrow strip of land along the north coast between Discovery Bay and Montego Bay. In these areas an average of less than 1,270 mm (50 inches) of rainfall per year has been experienced over a 90 year period (1870 - 1960).[9/]

Generally speaking, Jamaica may be divided into three rainfall zones:[9/]

(i) a heavy rainfall area with an annual average fall of over 2,540 mm (100 inches);

(ii) a moderate rainfall area with an annual average fall of 1,270 mm (50 - 100 inches);

(iii) a low rainfall area with an annual average fall of less than 1,270 mm (50 Inches).

Presented in Figure 1 is a histogram of monthly mean rainfall in Jamaica for the period of 1870 - 1960. The months of low rainfall are December, January, February and March. Whatever rainfall occurs during this period is chiefly orographic and reaches its minimum in March with an island average of 74 mm (2.90 inches). Periods of highest rainfall occur in May to June and August to November.

There is a transition period in April, when the rainfall steadily increases from the minimum reached in March to the summer maximum in May or June. A secondary transition period occurs in July, when the rainfall decreases slightly before the advent of the August to November rainy season.

In terms of rainfall intensity, Jamaica has recorded one of the highest point rainfall in 15 minutes among reporting stations around the world. Also on two occasions for which records are available, the island recorded the highest rainfall in the world for a six-day period.[12/]

The rainfall pattern of the experimental site at Olive River is strikingly similar to that of the average for the entire island, as shown in figures 1 and 2. as can be seen, total yearly average rainfall is 2,261 mm (89 inches) as computed for the ten year period 1969 - 1978 for which information is available. Driest months are December through March and the wettest months are April to June and August to October.

Days of maximum rainfall at the Wait-A-Bit station for the period of 1969 - 1978 are shown in Table 1.

Table I Maximum Daily Rainfall for Wait-A-Bit, Trelawny

Order	Dates occurred	Maximum daily rainfall
(1)	February 9, 1971	255.27 mm (10.05) inches
(2)	October 16, 1973	135.90 mm (5.35) inches
(3)	September 16, 1969	134.60 mm (5.30) inches)
(4)	December 9, 1969	135.60 mm (5.30 inches

(Selected dates during period 1969 - 1973)

The day on which the highest rainfall was recorded was February 9, 1971 having 255 mm of rainfall. This was followed by three other days of heavy rainfall in 1969 and 1973 when over 134 mm of rainfall was recorded on each of these days.

A standard rain gauge was installed within the run-off plot area at the Olive River Demonstration Centre, in April 1980. Daily rainfall is measured at 8:00 a.m. in the morning. The gauge stands 14 inches high, is 4 and 1/8 inches in diameter, and comes with rust-proof mounting bracket that is attached to a stake. The gauge measures each 0.2 mm to a maximum of 279 mm, and also no measuring stick is required.

2.2 Soils

The soil at the Olive River Demonstration Centre is classified locally as Wait-A-Bit clay (Map No. 95). In general, Wait-A-Bit clay is a dark brown clay having a good structure at a depth of 10 cm (4 inch), yellowish red clay with weak structure at a depth of about 30 cm (12 inch); and reddish yellow clay, with weak structure followed by reddish and grey mottling over rotten shale parent material.

The site where the run-off plots are located has been under fallow for several years. Prior to the construction of the run-off plots it was necessary to remove the top-soil in places in order to obtain a uniform gradient of 20°. However, this top-soil material was replaced prior to crop establishment.

2.3 Topography

The Olive River Demonstration Centre (consisting of 1.50 ha) is located in south Trelawny at a distance of about 10 km north-east of Christiana, and is typical of traditional hillside farming areas of Jamaica where yam is the main crop. The altitude of the area is about 820 metres (2,700 ft.) The average aspect of the area is sloped towards north-west with no distinct drainage system over the entire area. Because there is no waterway for adequate disposal of the excess run-off, the low sections of the plot have frequently been flooded and the upper section eroded by the surface run-off. Presented in Table 2 are the slope categories of the test site.

Table 2 Land area by slope classes and capabilities at the Olive River Demonstration Site, Trelawny

Slope (°)	Class	Capabilities	Area: ha (acres)
0° - 7°	C1	cultivable land 1	0.30 (0.76)
7° - 15°	C2	cultivable land 2	0.64 (1.57)
15° - 20°	C3	cultivable land 3	0.18 (0.45)
20° - 25°	C4	cultivable land 4	0.38 (0.95)
Total			1.50 (3.73)

2.4 Land Use Types

The present land use types before reclamation for development of the project consists largely of cultivable land, and idle land or ruinate*. The cultivated portion (0.86 ha) consisted of yam (0.23 ha). chocho (0.13 ha) and banana (0.50 ha). The idle land of 0.64 ha consisted of ruinate (0.3 ha), an old house situated on a lot (0.06 ha), and others including farm paths (0.28 ha).

*Ruinate is the local term given to land which has a potential for agricultural production, but which has been left idle, deliberately or otherwise to revert to bush, as part of a fertility regeneration process.

DESIGN AND CONSTRUCTION OF RUN OFF PLOTS

3.1 Plot Size

Ideally, soil run-off plots should be representative of the agro-climatic conditions of the particular watershed being studied. This implies a rather large surface area from which soil sediment and drainage water is collected and measured. However, construction and maintenance costs of large run-off plots are very high. Notwithstanding the consideration that plot size is closely related to the magnitude of surface run-off and erosion, it is also true that the actual amount of surface run-off from plots is less important than differences to be detected between treatments.

Run-off plots are either square or rectangular shaped. Square shaped plots have an advantage in that the ratio of plot border to plot area is less than that for rectangular shaped plots. However, the latter has a distinct advantange in that a larger slope is provided for a given area.

At Olive River, yam (Dioscorea spp.) constitutes the principal crop. Not unlike other hillsides of Jamaica, the yam 'head' or basal portion of the tuber is planted on conical hills which are constructed across the slope at a density of 2,500 hills per hectare (one hill/4m^2), with each hill having on the average two plants. This method of yam cultivation leads to serious soil loss which was reported to be 133 tons of oven-dried soil per hectare per year on a 17° slope, where annual rainfall was about 2,500 mm.[8/]

Determination of the size of the run-off plot was predicated inter alia on the morphology and growth characteristics of the principal test crop, viz. yam, which when properly staked can attain heights of approximately 10 metres. On these considerations the size of the run-off plot was fixed at 15.8 m x 2.7 m along a 20° slope or 14.8 m x 2.7 m horizontally, giving a run-off area of 40 m^2 (0.004 ha). Depicted in Figure 3 is the relationship between the slope area and the horizontal area of the run-off plot. As presented in Figure 4, a battery of eight contiguous run-off plots was constructed along the slope to accommodate four soil conservation cum cropping system treatments.

Each plot was delineated by boundary walls (Figure 5-1) made of hollow concrete blocks (40 x 18 x 14 cm). The height of the boundary walls is approximately 35 cm from the soil surface, and the width inclusive of cement plastering work is 15 cm. To divert rainfall water from the walls away from the test plots, a V-shaped crest was mounted on the top of each wall (Figure 5-2). To protect the plots against external seepage an earthen bank was constructed across the upper end of the battery of plots and along the two sloping sides. Storm water was also prevented from infiltrating the plots by means of boundary drains which were constructed alongside the earthen bank. The concrete boundary walls of each plot are permanent and immovable. To ensure against leaks or seepages resulting from burrowing animals such as rodents, it is imperative that periodic checks be conducted on all the boundary walls. Reinforcement of each boundary wall was effected by means of a concrete pavement having a width of 20 cm and a depth of 11 cm (Figure 5-2). These concrete pavements (one per plot) also served:

(i) as foot paths to service the plots and crops;

(ii) to prevent scouring erosion from occurring along the boundary wall.

3.2 Collection Troughs and Tanks

Depicted in Figures 6-1, 6-2 and 6-3 are various iso-metric drawings of the soil-water collecting trough. It is positioned across the lower end of each plot and serves as a weir for sediment run-off, most of which will finally enter a set of two sediment/suspension tanks (Figure 7).

The trough is made of galvanized sheet which has the distinct advantage of being malleable. This makes it possible to adjust its height to the level of the plot as soil subsides with erosion. The trough is connected to the plot by means of a tongue which is inserted horizontally across the entire width of the plot (Figure 7) and approximately 20 cm from the edge of the plot. This tongue serves to channel run-off material into the trough as well as to protect against leakage and seepages. The dimensions of the collection trough are 270 cm x 30 cm x 25 cm (depth). To prevent off-plot debris from entering the trough it was fitted with a cover which was also made of galvanized sheet.

As presented in Figure 7 run-off material from each of eight of the collection troughs is conveyed to sediment tanks by means of a rectangular conduit (100 cm x 20 cm x 15 cm) made of galvanized sheet. Two 55 gallon (211 liter) capacity metal drums (85 cm in height and 57.5 cm in diameter) were irstalled for each run-off plot for the collection of run-off 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. To reduce turbulence in the sediment tank (A) wooden sticks are placed in the conduit along the direction of flow. Over-flow run-off material from tank A is conveyed to the suspension tank B by means of a metal pipe having a length of 60 cm and inner diameter of 5 cm, and which was welded to the upper end of the drum A. A removable plug was inserted at the lower end of tank B to drain off the soil-water suspension after appropriate measurements were recorded. The pipe from drum A is supported by means of metal bars which were welded to the side of the drum. To service the eight run-off plots a total of 16 tanks were installed, each resting on a concrete base having a thickness of 10 cm. To facilitate the sampling of soil run-off measurements from the collection troughs a continuous 80 cm wide concrete pavement was constructed across the lower end of the eight plots. This pavement also serves to reinforce the plots against possible slippage down-hill.

3.3 Soil Conservation Treatments

It was mentioned earlier that the objective of this study was to test and develop soil conservation methods other than bench-terracing for the reason that terraces are very costly to build and maintain. In designing the treatments, much importance was given to simplicity and ease of adoption by the farmer of the system or systems to be recommended. These considerations also took into account the cropping systems which the farmer is traditionally accustomed to, and possible ways of enhancing farm productivity with a modicum of technological change. Viewed in toto, the soil conservation treatments were evaluated together with cropping patterns that are relevant to the area and the farming community.

Consequently, the following four basic soil conservation treatments and cropping patterns were selected for evaluation during the first cropping cycle (March 1980 to February 1981). Arrangement of the soil conservation treatments and cropping systems is shown in Figure 8.

Soil Conservation Treatment		Cropping Pattern
(i)	check, i.e. individual hills	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

3.4 Plot Preparation and Amendment

Following the construction of the run-off plots, soils were sampled for determination of nutrient status. The results are presented in Table 3 (page 14).

The test soil is very highly acidic (pH 4.8), low in levels of available nitrogen, phosphorous, magnesium, calcium, zinc and copper and medium in levels of available potassium and manganese. To ameliorate against acidity and low organic matter content, all plots received a rate of 3 tons/ha of $CaCO_3$ in the form of marl, and decomposed sewage sludge respectively. Following this application plots were forked and the appropriate conservation treatments were installed. In cases where individual hills were constructed, hills were spaced at a distance of 1.5 m along the contour and 1.4 m along the slope. The height of the hill from the soil surface was approximately 60 cm. Hillside ditches (Figure 9) having a width of 2.5 m were constructed approximately mid-way down the plots. Contour mounds extended across the plots and were spaced 1.5 m apart with a height of 60 cm at the peak. Grass buffer strips (Figure 10) having a width of 1.3 m were established about mid-way down the plot by planting Napier grass (Pennisetum Purpureum). This is one of the more promising species of grass for the hillsides of Jamaica. It establishes with relative ease and serves as a good source of fodder for cattle.

Table 3 Chemical characteristics of the test soil at Olive River, Trelawny, classified locally as Wait-A-Bit clay (soil No. 95) at the beginning of the soil-loss-cropping systems study (February 1980).

Characteristics	Soil layer (cm) 0 - 20	20 - 40
pH	4.8	4.7
Cation exchange capacity (meg/100g)	23.2	23.0
Ca (meg/100g)[a]	4.3	2.1
Mg (meg/100g)	1.0	0.8
K (meg/100g)	0.6	0.5
Exchangeable Al (meg/100g)	9.3	9.4
K_2O (ppm)	287.0	215.0
P_2O_5 (ppm)	36.0	36.0
N (%) Kjeldahl	0.14	0.11
Organic matter (%)	2.7	2.0
Cu (ppm)	1.6	1.3
Fe (ppm)	109.0	105.0
Mn (ppm)	14.8	11.5
Zn (ppm)	2.4	1.1

Ca and Mg were determined using N KCl extract; K was determined using 0.5 N CH_3COOH extract.

Since the amount of run-off sediment for a given slope is related to such factors as gradient, frequency and intensity of rainfall, soil texture and depth and crop cover, it was decided to introduce the concept of intercropping whereby more than one crop is grown simultaneously on the same plot of land. This system of farming is ideally suited to small hillside farms in Jamaica insofar as (i) employment generation; (ii) farm income ; (iii) productivity per unit area per unit time; and (iv) enhancing nutritional profiles of farm families (Wahab et al 1980).[13/] An ideal cropping pattern for rainfed agriculture is one which makes maximal use of rainfall water, available

soil moisture and crop nutrients, plot space and incoming solar radiation. Based on these considerations and past experience on the "Allsides Hillside Farming Development Project",[13/] yams were intercropped in sequence with Irish potato, radish and peanut as shown in Figure 8.

3.5 Crop and Soil Management

Yellow yam (Dioscorea cayenensis) "heads" (propagation material) were planted on March 25, 1980. "Heads" were purchased from farmers within the project area three to four weeks prior to sowing. Irrespective of soil conservation treatment cum cropping pattern each plot received the same number of 'heads' (32) to produce an expected population 8,000 yam plants per hectare.

As presented in the field layout diagram (Figure 8) 20 individual hills were constructed per plot where the traditional individual hill method was employed for growing yam; (Treatment No. I and II) with each of 12 hills receiving two 'heads' and each of the remaining eight hills receiving one 'head'. Again, using the traditional system each hill was provided with one bamboo stake, of 6 m length, to accommodate the twining yam vine. In the other three treatments, however, greater staking efficiency was achieved by the placement of one bamboo stake per four yam vines.

For treatments in which planting was done on contour mounds (Treatments No. III and IV), yam 'heads' were placed at 62 cm intervals along the mound, with mounds spaced 1.5 m apart. Following sprouting (at three to four weeks' from planting) vines were twined around the stakes and allowed to develop until maturity. The crop was harvested on January 29, 1981, that is 279 days after sowing, following the onset of leaf senescence.

Irish potato was planted in rows spaced 40 cm apart at intervals of 30 cm within the row giving a density of 50,000 plants/ha. Following harvest of the Irish potato crop, radish was sown in rows spaced 30 cm apart at intervals of 10 cm within the row. This resulted in a plant population of approximately 125,000 per hectare. After the removal of the radish crop, peanuts were sown in rows spaced 40 cm apart and at an interval of 20 cm within the row. This gave an expected density of approximately 63,000 plants/ha.

. With respect to fertilizer application, each cropping system received the equivalent of 1,460 kg/ha of a mixture consisting of N, P_2O_5 and K_2O in the ratio of 12:24:12 plus an additional application of 60 kg/ha of elemental nitrogen in the form of urea, or ammonium sulphate. Applications were split as shown in Table 4.

Table 4 Fertilizer regime for soil conservation cum cropping system trials at Olive River, Trelawny (1980 - 1981)

Cropping System	Time of Application	Fertilizer $N:P_2O_5:K_2O$ 12:24:12 (Kg/ha)	N Kg/ha
Yam as a sole crop	6 weeks from planting	730	0
	14 weeks from planting	730	0
Yam cropped with Irish potato followed by radish and peanut			
Yam intercrop	6 weeks from planting	300	0
	14 weeks from planting	300	0
	28 weeks from planting	130	20
Irish potato	At time of sowing	365	0
	At flowering	0	20
Radish intercrop	No fertilizer applied	0	0
Peanut intercrop	At time of sowing	365	0
	At flowering	0	20

In the case of yams, fertilizers were placed in bands circularly 15 cm away from the stem, at a depth of 5 - 7.5 cm. For the intercrops (with the exception of radish), applications were made at sowing directly in the furrow at 5 - 7.5 cm below the seeding depth. At the flowering stages of the intercrops, urea was placed in bands circularly 5 - 7.5 cm away from the furrow at a depth of 5 - 7.5 cm.

Weeding was effected manually. Control against diseases and pests was achieved by spray applications as often as necessary.

4. RECORDS AND MEASUREMENTS

4.1 Measurement of Rainfall

Following construction of the run-off plots, rain gauge was installed after which daily records of rainfall were maintained. Measurements are taken at 8.00 a.m.

4.2 Measurement of Soil Loss

Following each period of a "very heavy 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 determined and recorded on the "Data Sheet for Measurement of Soil Loss " (Table 5) and also on the "Soil Moisture Data Sheet" (Table 6). For determination of soil loss, the following procedure is used:

(a) the weights of the wet soil sediment contained in both the trough and tank A are recorded;

(b) from these sediment materials three sub-samples (aliquots) are collected for moisture content determination. The soil-water sediments were oven-dried at 105°C for 72 hours after which final weight determinations were made;

(c) the per-cent moisture of the sediment samples was then calculated as follows:-

$$\% \text{ moisture} = \frac{\text{wet weight - dry weight of sample}}{\text{dry weight}} \times 100$$

The moisture content of the soil-sediment/suspension within the trough and tank was estimated by averaging the three values. A simple procedure for measurement and calculation of soil-loss is then made.

4.3 Measurement of Run-Off Water

In this study, the amount of run-off water is not reported. This decision is based on the experimental results of Smithfield that "the effects of treatment on surface run-off were non-existent or very small". However, the amount of run-off water including sedimentations could be measured and recorded for future reference. The depths of run-off water in tanks A (sediment tank A) and B (in the case of overflow from tank A) could be estimated by the use of a graduated steel tape ruler. Using the formula of multiplying depth of tank by area, it is then possible to compute the volume of run-off water in tanks A and B.

Table 5 Data sheet for measurement of soil loss

Duration of rainfall received: _____

Date of field sample measurement: _____ Field measurement by: _____

Total rainfall for the period: _____(mm) Lab. & Calculation by: _____

Sediment sample no.		Plot No.	1	2	3	4	5	6	7	8	Remarks
		Treatment No.	T-III	T-I	T-II	T-VI	T-III	T-II	T-IV	T-I	
Net sediment volume of trough (litres)											
Total net wet weight of sediment trough (kg)											
Sediment sample (x)	Can no.										
	% moisture										
Sediment sample (y)	Can no.										
	% moisture										
Sediment sample (z)	Can no.										
	% moisture										
Mean % moisture											
Dry sediment weight of trough (kg)											
Net sediment volume of tank (A) (litres)											
Total net wet weight of sediment of tank (A) (kg)											
Sediment sample (x)	Can no.										
	% moisture										
Sediment sample (y)	Can no.										
	% moisture										
Sediment sample (z)	Can no.										
	% moisture										
Mean % moisture											
Dry sediment weight of tank (A) (kg)											
Total dry sediment weight of plot (kg)											

Table 6 Soil moisture data sheet Sample date: _____

Sample ( ) Sampled by: _____

Can no.	Wt. of can + lid (gram)	Wt. of can + lid + wet soil sample	Wt. of can + lid + dry soil sample	Wt. of wet sample	Wt. of dry sample	% moisture
1.	49.3					
2.	49.1					
3.	49.1					
4.	50.0					
5.	49.6					
6.	49.3					
7.	49.1					
8.	49.3					
9.	49.8					
10.	49.0					
11.	49.3					
12.	49.2					
13.	49.4					
14.	49.8					
15.	48.8					
16.	49.1					
17.	49.7					
18.	49.2					
19.	49.4					
20.	48.8					
21.	49.5					
22.	49.5					
23.	49.0					
24.	49.6					

4.4 Sediment Measurement and Sampling in the Field

The run-off water is drained off after its depth is recorded and after the suspended soil particles have settled. At times of frequent storms, it is impracticable to carry out this exercise because one storm may be followed by another before solids can settle. In this case a coagulant such as alum or lime is used to facilitate the settling of the soil-sediment suspension. Removal of the run-off water is achieved by siphoning, in which a 10 mm plastic hose of appropriate length is used.

Net sediment volume of tank A is measured by using a plastic bucket calibrated in metric units. Wet sediments weights are then recorded, after which moisture content determinations are made and weight of soil loss is expressed on an oven-dried basis.

4.5 Measurement of Crop Production

To eliminate the possible effect of seed size on yield, yam heads were selected for uniformity of weight insofar as this was possible. At planting, each head was weighed and recorded so that following harvest of the yam tubers any relationships between size of planting material and tube yield could be determined. Each plot received 32 yam heads which averaged 0.87 kg (1.9 lb) each or 8.7 tonnes/ha.

In the case of potato seed, material of the red Pontiac variety was used. Each plot was sown with approximately the same number of seed pieces (133) giving a population of 33,000/ha. Weight of seed material per plot was kept constant at 10.4 kg/plot or 2.6 tonnes per hectare.

Radish was directly seeded at the recommended rate and peanuts were sown at the rate of 75 kg/ha or 300 grams/plot giving a population of 150,000/ha.

At harvest, fresh tuber weight of the entire biomass for yams was recorded after which that portion of the proximal end to be used as planting material was severed and weighed. The remainder of the yam tuber was separated into marketable or unmarketable portions using firmness, appearance, shape and disease-free condition as criteria for marketable material.

Potatoes were separated into marketable material on the basis of size, firmness and disease and insect free condition. Tubers which were mature, but small, were considered as seed material, whereas undeveloped, immature tubers were classified as unmarketable.

Radishes were considered marketable if they were round to oval and not larger than a ping-pong ball.

The peanut intercrop was abandoned after it became clear that due to the excessive shading from the yam canopy, normal crop growth and development were impaired.

5. RESULTS AND DISCUSSIONS

In the interest of simplicity and coherency, the results of the soil loss will be presented first, followed by the crop yield data.

5.1 Soil Loss

Rainfall data for the period under discussion are presented in Table 7 and Annexes 1, 2 and 3. Presented in Annexes 4 and 5, and Tables 7 and 8 are the data pertaining to rainfall and soil loss studies.

Table 7 Dates of soil sediment collection and rainfall received during the period April 1980 - March 1981 at the Olive River Demonstration Site, Lowe River, Trelawny

Sampling interval	Period	Length of Interval (days)	Number of rainy days	Rainfall during interval		Cumulative rainfall	
				mm	inches	mm	inches
	1980						
1	April 26 - May 8	13	5	87.9	3.46	87.9	3.46
2	May 9 - May 20	12	6	92.8	3.65	180.7	7.11
3	May 21 - May 27	7	3	83.3	3.28	264.0	10.39
4	May 28 - June 10	14	7	157.2	6.19	421.2	16.58
5	June 11 - July 4	24	2	55.0	2.17	476.2	18.75
6	July 5 - July 22	18	8	81.9	3.22	558.1	21.97
7	July 23 - Aug. 12	21	3	229.1	9.02	787.2	30.99
8	Aug. 13 - Sept. 9	28	8	66.4	2.61	852.4	33.56
9	Sept. 10 - Oct. 7	28	10	66.3	2.61	919.9	36.22
10	Oct. 8 - Dec. 10	64	18	154.5	6.08	1,074.4	42.30
	1981						
11	Dec. 11 - March 3	83	19	220.7	8.69	1,295.1	50.98
	Total	312	89	1,295.1	50.98	1,295.1	50.98

Table 8 Result summarized of the run-off experiment plot for soil loss measurement

Treatment No.	Oven-dried weight of soil loss				Ratio to T - I (%)	% reduction from T - I	Treatment comparisons for effectiveness (times)
	per plot (kg)	ton/ha	ton/ac	depth (mm/yr)			
T-I	728.65	178.97	71.25	12.41	100.0	-	0
T-II	421.07	102.77	40.91	7.17	57.79	42.21	1.7 0
T-III	200.96	49.05	19.53	3.42	27.58	72.42	3.6 2.1 0
T-IV	172.08	42.84	17.06	2.93	23.36	76.64	4.2 2.5 0

A rain gauge was installed on April 26, 1980, the date on which construction of the run-off plots were completed. However, it should be recalled that the yam and Irish potato crops were planted on March 26, 1980.

During the period April 26 to May 8 (13 days) a total of 88 mm of rain fell over the project area. Soil loss was greatest from the control plot (19.32 t/ha)* and least (5.84 t/ha) from plots having contour mounds and a grass buffer strip. In practice, the control plot could be considered as not having any crop canopy whatsoever since it was cropped to yams alone which initiates sprouting during the first eight weeks followed by another eight weeks of rapid shoot elongation and leaf development. In the other run-off plot, although the yam crop was developing at the same rate as in the check plots, by 44 days the Irish potato crop had germinated and established a good crop cover, and by 50 days floral initiation had been completed. With continued rains over the 19 day period (May 9 - May 27), the check plots again lost the most soil (63.5 t/ha) and the plots having continuous mounds with the grass strip (treatment 4) lost the least soil (10.54 t/ha), a reduction of 85%. By merely constructing a hillside ditch midway down the plot, and growing yams together with Irish potatoes, soil loss over the first 32 days of the study (April 26 - May 27) during which time 264 mm of rain fell, decreased from that of the check plot by 57% (83 versus 36 t/ha of oven-dry soil).

*Throughout the text t/ha signifies 1,000 kg/ha.

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. To illustrate, during the 38-day period extending from May 28 to July 4, during which 212 mm of rainfall was recorded, the check plots lost an equivalent of 36.7 t/ha of oven-dry soil whereas when the yam was intercropped with Irish potato using the traditional yam hills, but with a hillside ditch, soil loss was reduced to 7.32 t/ha or by 80%.

Further, when the effects of the intercrop (i.e. Irish potato) are separated from the main treatment effects (i.e. traditional hills versus contour mounds, or traditional hills with hillside ditch), a reduction in soil loss of 85% (7.32 vs 1.13 t/ha) can be achieved. That a good crop cover leads to significant reduction in soil loss is further substantiated by the data obtained during the 28-day interval between August 13 and September 9, during which there were eight days of rain totalling 66.4 mm. The yam crop was experiencing its most active phase of growth and where radish was intercropped (July 29 to September 10) this too had attained maximum crop canopy. During this period soil loss from the check plots amounted to 4.31 t/ha whereas with the introduction of a hillside ditch and an intercrop of radish, soil loss decreased to 4.25 t/ha. However, plots having contour mounds and a grass buffer strip registered the lowest soil loss (1.8 t/ha).

Following germination and early crop development of the peanut intercrop, the crop was abandoned due to excessive shading from the yam vines. This meant that through harvest of the yam on January 29, 1981 all plots were similarly affected by the yam crop vis-a-vis canopy and soil run-off resulting from rainfall. During the final development phase of the yam crop (September onwards) a total of 400 mm of rainfall was recorded. This occurred over 42 rainy days. The final sampling date for soil loss determination was on March 3, 1981, following four rainy days in February when 35.8 mm of rain fell. During the final phase of the yam crop cycle, check plots lost 12.84 t/ha of oven-dry soil whereas plots treated with contour mounds and a grass buffer strip registered 6.28 t/ha of soil loss or a reduction of 51% from the control plot.

When the soil loss values are totalled for the entire crop year (Table 8) it is seen that during a period of 312 days, 1,300 mm (5 ins.) of rain fell in 89 rainy days. Soil loss from the check plots on which yams were grown on individual hills without a hillside ditch amounted to 179 tonnes of oven-dry soil per hectare. However, by constructing a hillside ditch midway down the plot and intercropping yam with Irish potato and radish, soil loss decreased by 42% to 103 t/ha. There was an even more dramatic reduction in soil loss when yams were intercropped with Irish potato and radish on contour mounds interrupted by a hillside ditch. In this treatment (No. 3) soil loss amounted to 49 t/ha or 72% less than the control plot. The most effective treatment was that in which yams were intercropped as in the preceding treatment, but rather than interrupt the velocity of water flow downhill by a hillside ditch, a buffer grass strip of Napier grass was established. This reduced soil loss by 76%, in comparison with that of the control plot. In other words, under the conditions of the experiment one acre-six inch furrow-slice of soil can be lost in 12.5 years using the traditional yam cultivation method. However, intercropping yams with short cycle crops such as Irish potato and radish on continuous contour mounds interrupted by a grass strip at fixed intervals, can retard soil loss to the extent where 52 years would be required to experience a soil loss of the upper 15 cm soil layer.

5.2 Crop Production

Results of crop yields for the treatments are presented in Tables 9 and 10. Gross yam tuber yields were highest with significant difference for the check plot (62.23 t/ha) followed by treatment 2 (53.98 t/ha), and lowest for treatment 3 (42.40 t/ha), and treatment 4 (42.11 t/ha), although there was no significant difference in yields between the latter two treatments. It is likely that the intercrops depressed yam yields due to competition for available nutrients, moisture and incoming solar radiation.

In marketable yam yields, treatment 2 plot yielded the highest (29.94 t/ha) followed by the check plot (28.80 t/ha), and lowest for treatment 4 (17.18 t/ha) followed by treatment 3 (16.51 t/ha). Where yams were intercropped with Irish potatoes and radishes, marketable potato yields ranged from 7 to 9 t/ha, whereas yields of marketable radish ranged from 700 to 900 kg/ha.

Table 9 Yellow yam tuber yields of soil run-off plots treated with conservation measures cum cropping system at the Olive River Demonstration Site, Trelawny, during the 1980-81 cropping cycle[1/]

Soil conservation treatment	Cropping pattern	Gross tuber yield (t/ha)	Marketable tuber yield (t/ha)	Production of 'new heads' for planting (t/ha)
Individual hills (check)	Yam as sole crop	62.23	28.80	14.69
Individual hills with hillside ditch	Yam + Irish potato + radish	53.98	29.94	11.29
Continuous contour mounds with hillside ditch	Yam + Irish potato + radish	42.20	16.51	13.75
Continuous contour mounds with grass buffer strip	Yam + Irish potato + radish	42.11	17.18	13.16

[1/] Values are the means of two replications

Table 10 Saleable yields of yellow yam and intercrops grown on soil run-off plots at the Olive River Demonstration Site, Trelawny, during the 1980-81 cropping cycle[1/]

Soil conservation treatment	Cropping Pattern	Saleable yields				
		Yam		Irish potato		Radish
		Marketable (t/ha)	'New heads'	Marketable (t/ha)	Seed material	(kg/ha)
Individual hills (check)	Yam as sole crop	28.80	14.69	-	-	-
Individual hills with hillside ditch	Yam + Irish potato + radish	29.94	11.29	7.14	3.63	700
Continuous contour mounds with hillside ditch	Yam + Irish potato + radish	16.51	13.75	8.63	3.33	863
Continuous contour mounds with grass buffer strip	Yam + Irish potato + radish	17.18	13.16	7.6	3.96	588

[1/] Values are the means of two replications

Notwithstanding this, due to the high market prices offered for Irish potato and the non-traditional radish crop, overall farm income for treatments 2, 3 and 4 will exceed that for the check treatment. Also, by planting these short-term crops the subsistence farmer could enhance his cash flow position and nutritional profile, while at the same time minimizing his farming risks and reducing soil erosion.

6. CONCLUSION

With the aim of ascertaining appropriate soil conservation methods other than bench terracing, for crop production on hilly lands, an experiment using run-off plots has been conducted at the Olive River Soil Conservation Experiment Station, Trelawny, Jamaica. The Experiment Station is located at an elevation of about 820 metres above sea level and the soil is classified locally as Wait-A-Bit clay (Map No. 95).

The experiment consisted of eight run-off plots representing four treatments replicated twice. Plot size was 40 m^2 (2.7 m wide and 15.8 m long) along a slope of 20°. During the first year of the trial, April 1980 to March 1981, a total of 1,300 mm rain fell over 89 rainy days. During this time, eleven samplings were made of soil sediment for estimation of soil loss. Cropping pattern consisted of yam grown as a monocrop, or yam grown in association with Irish potato, radish and peanut.

Soil loss from the check plots (T-I) on which yams were grown on individual hills without a hillside ditch, amounted to 179 tons of oven-dry soil per hectare. However, by constructing a hillside ditch and intercropping yam with Irish potato and radish (T-II), soil loss declined by 42% to 103 t/ha. A further reduction in soil loss was achieved by intercropping yam with Irish potato and radish on continuous contour mounds interrupted by a hillside ditch (T-III). This treatment resulted in a soil loss of 49 t/ha or 72% less than the check plot. Greatest reduction in soil loss was observed from plots of yam intercropped with Irish potato and radish on continuous contour mounds with a grass buffer strip (T-IV), in which soil loss amounted to 43 t/ha or 76% less than the check plot.

Marketable yam yields were highest for the check plot (29 t/ha) and treatment II (30 t/ha), and lowest for treatments III and IV plots (17 t/ha). Where yam was intercropped with Irish potato and radish, marketable potato yields ranged from 7 to 9 t/ha, whereas yields of marketable radish ranged from 700 to 900 kg/ha.

The first year's results are very encouraging in terms of providing a factual basis for assisting Government in modifying its policy with respect to subsidizing soil conservation work in agriculture for the island. Bench terraces, although highly productive, are very costly and the alternative soil conservation measures being evaluated are simpler and significantly less expensive.

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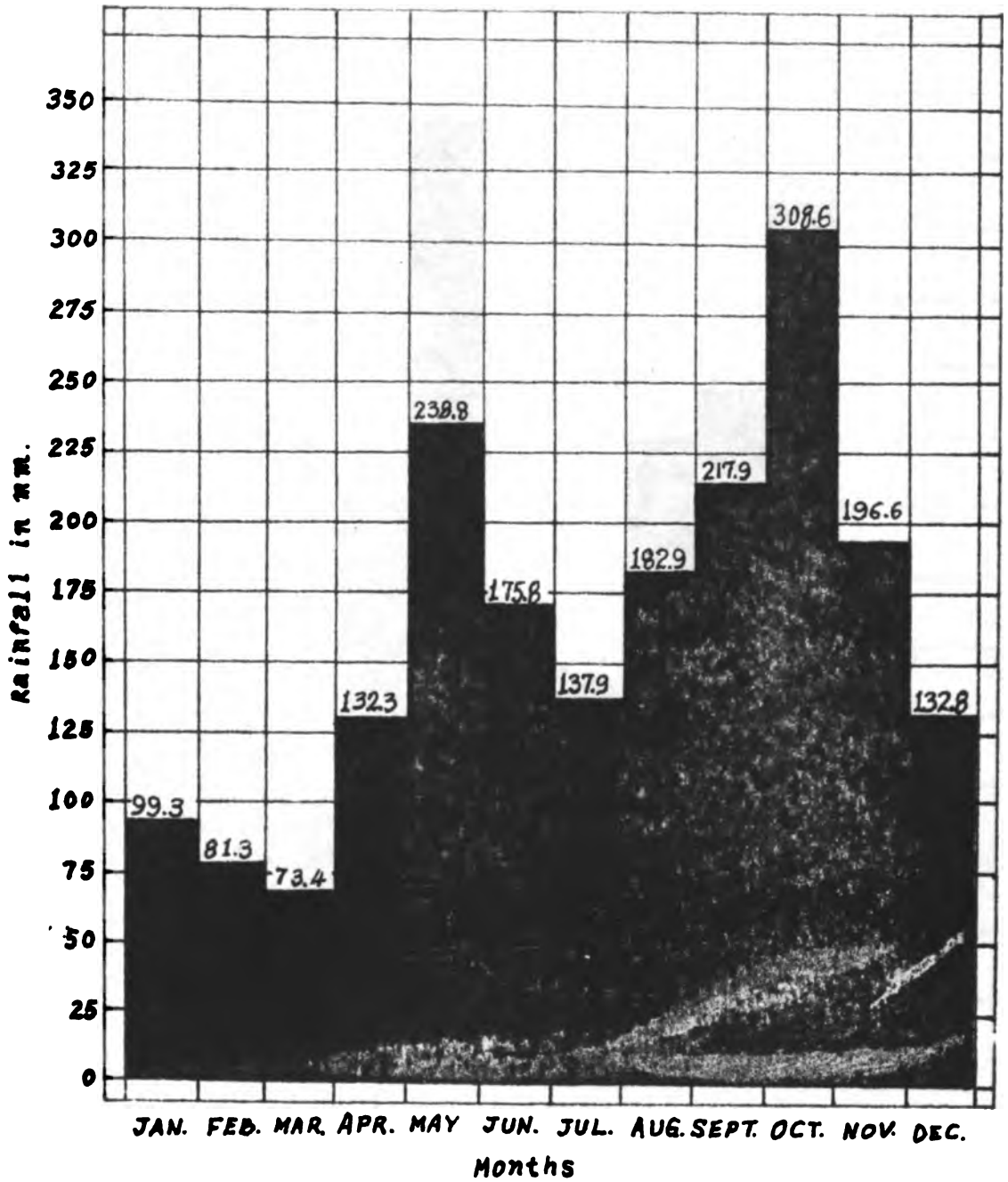
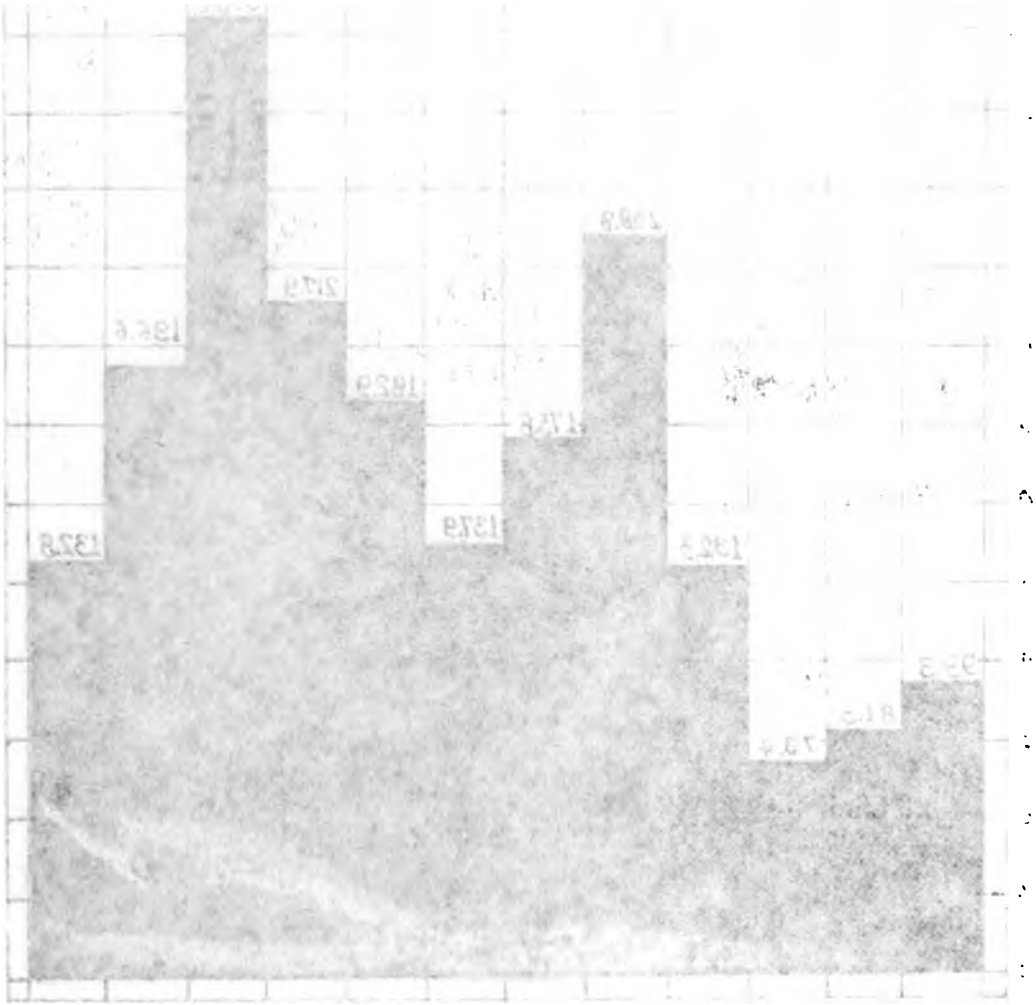


Fig. 1 Histogram of monthly mean rainfall totals Jamaica (1870-1960)



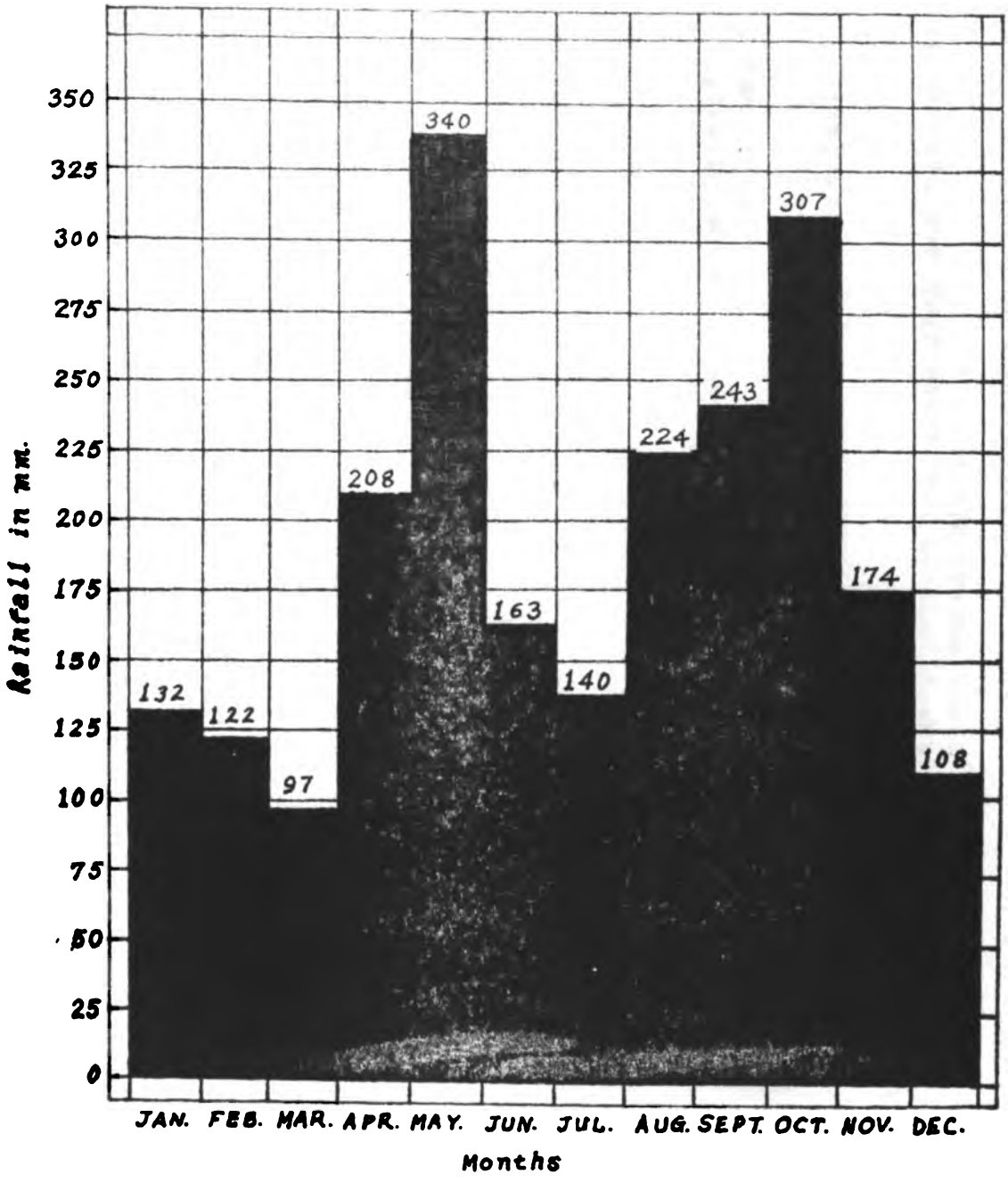
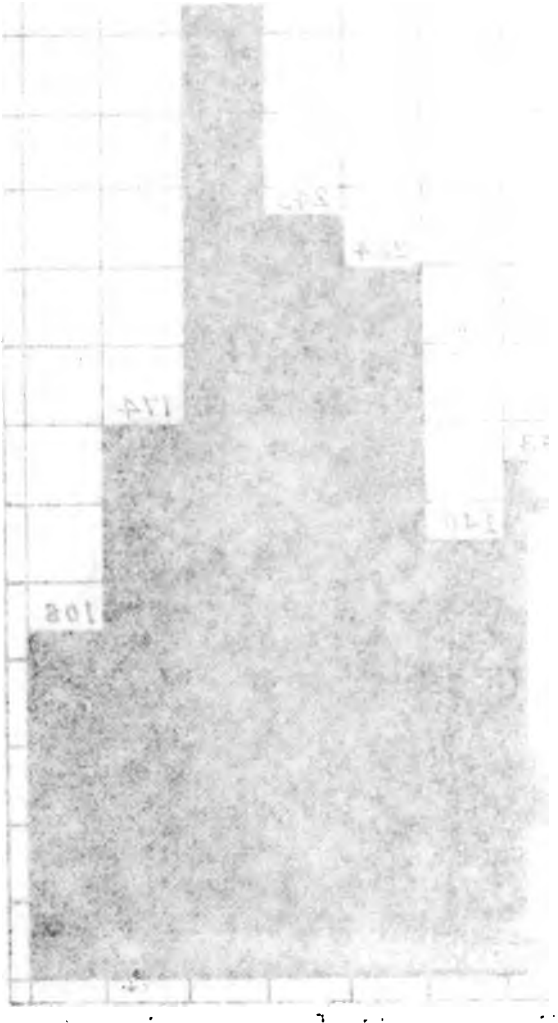


Fig. 2 Histogram of monthly mean rainfall totals
Wait-A Bit (1969-1978)



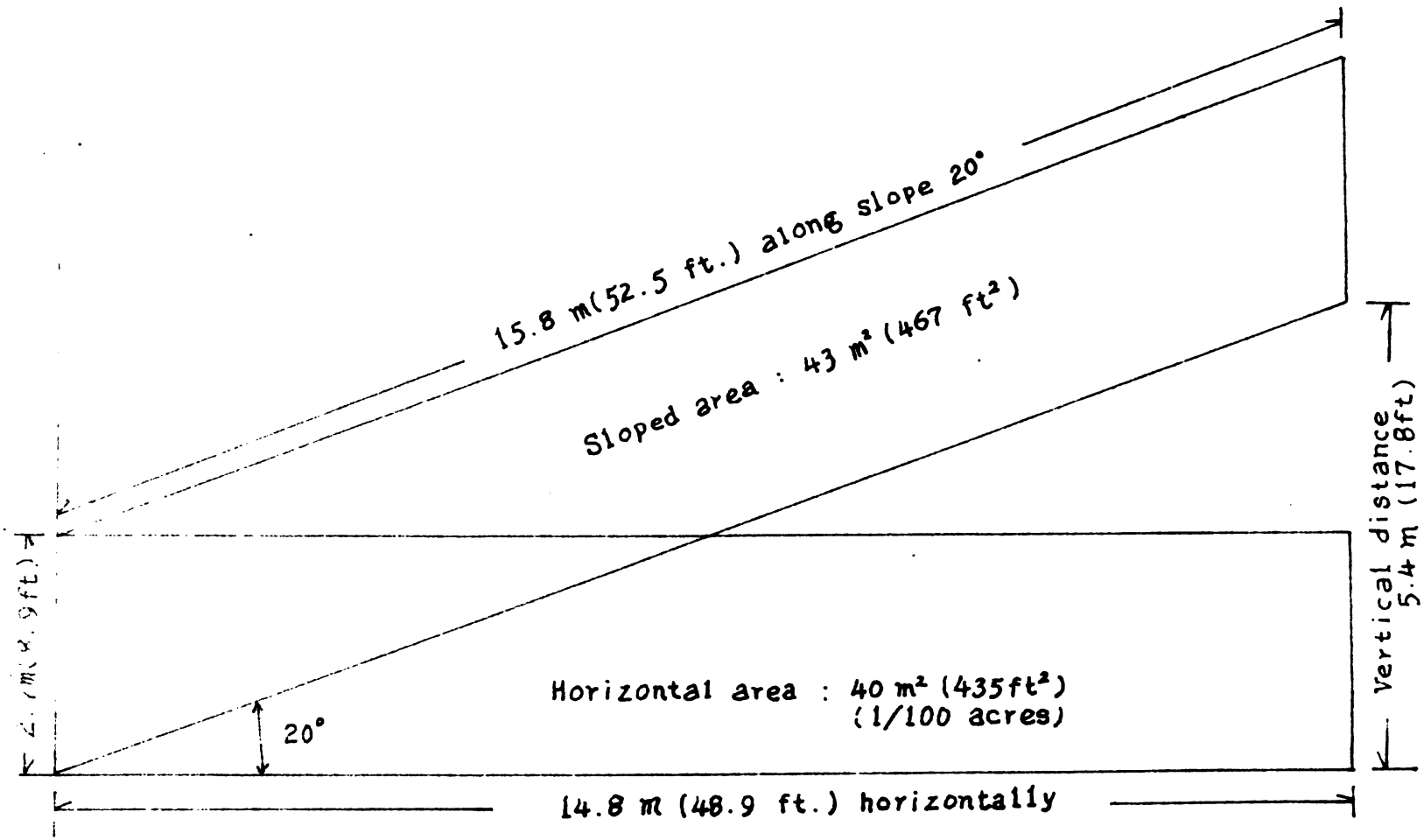


Fig.3 Relationship between the slope area and horizontal area of the experimental plots

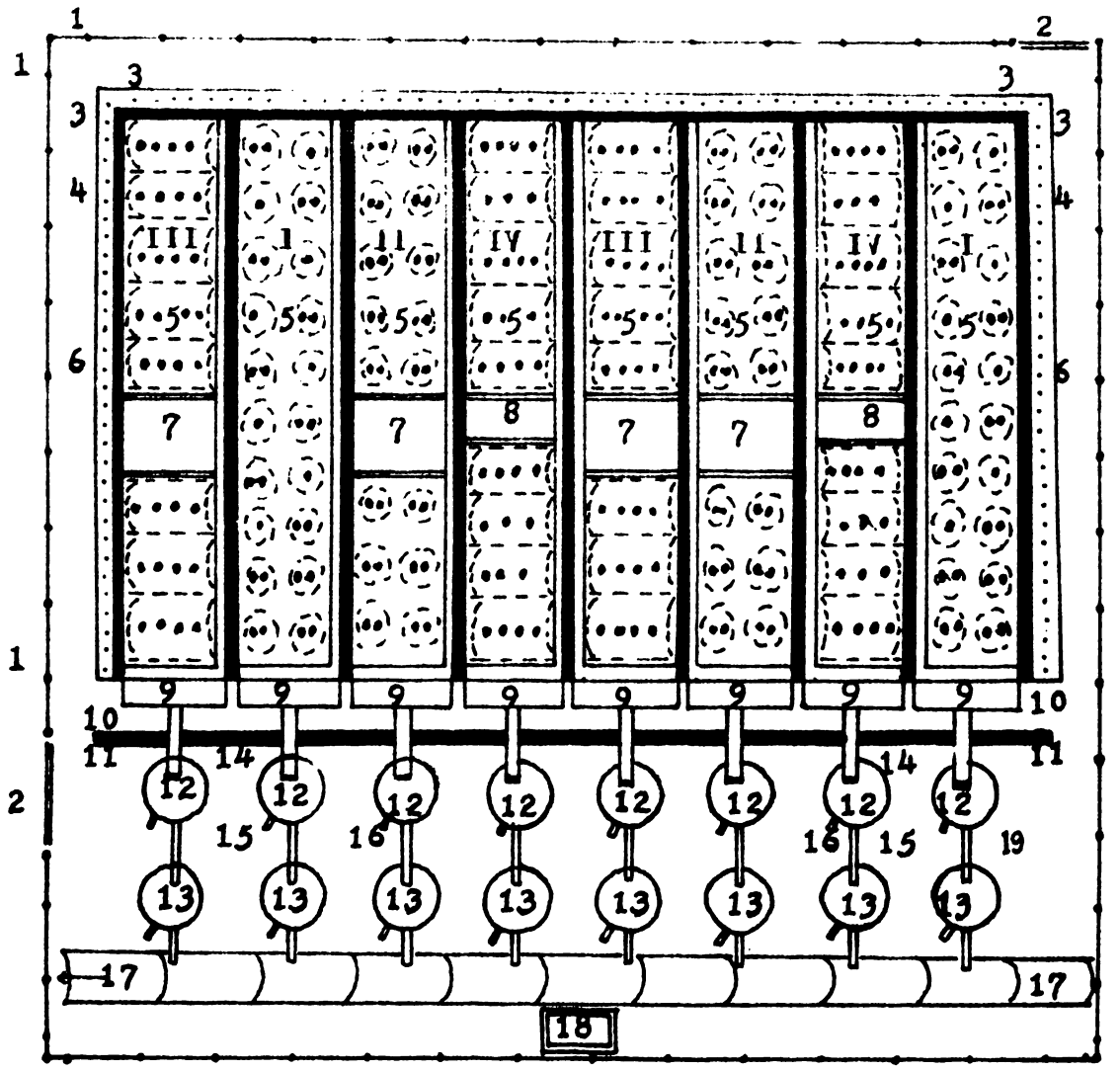


Fig.4 Top-view of layout of the run-off experiment plots

Legends

1 Barb-wire fence
2 Entrance gate
3 Earth wall
4 Plot boundary wall
5 Plot area
6 Plot pavement
7 Hillside ditch
8 Grass buffer strip
9 Collection trough
10 Concrete base
11 Retaining wall
12 Storage tank (A)
13 Storage tank (B)
14 Outlet pipe (a)
15 Outlet pipe (b)
16 Drainage pipe
17 Drainage way
18 Rain gauge
19 Mettle pavement

I, II, III, IV : Treatment No.

Yams on individual hill

Yams on contour mound

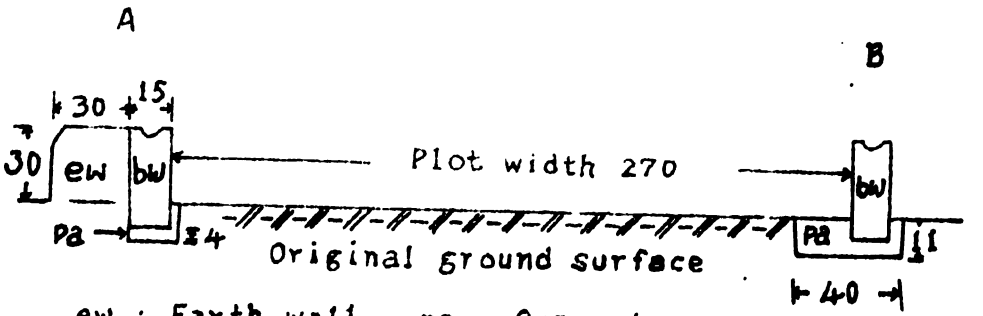


Fig.5-1 Cross section of a plot and boundaries (unit : cm)

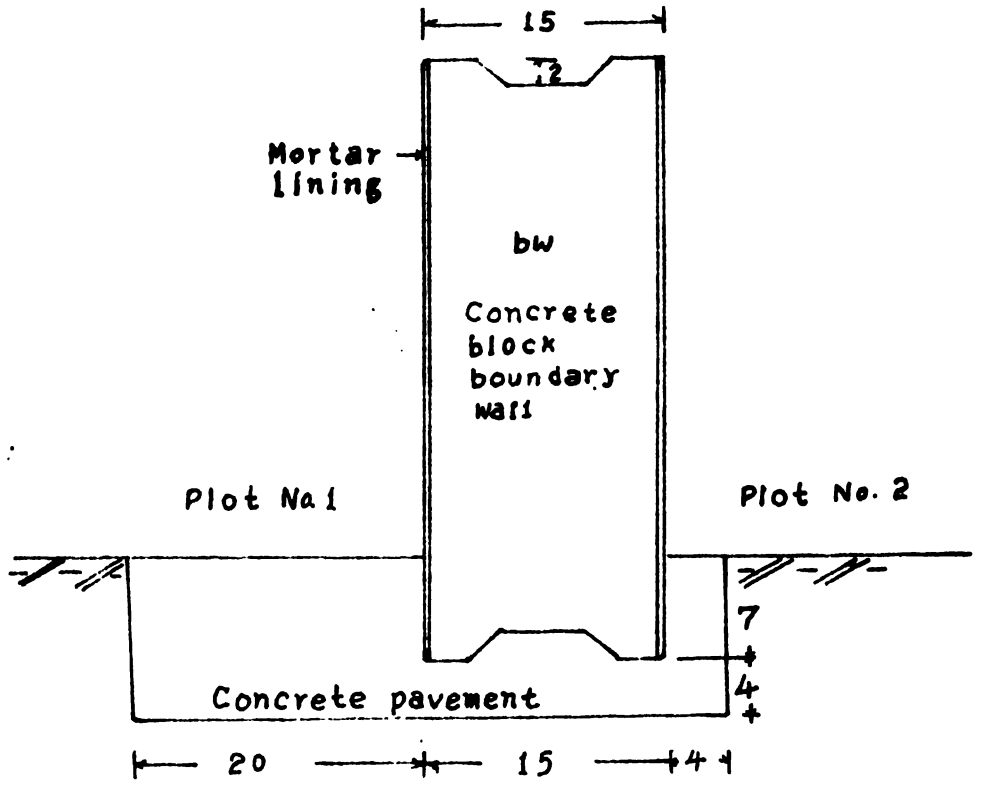


Fig.5-2 Cross section of boundary wall and pavement (unit : cm)

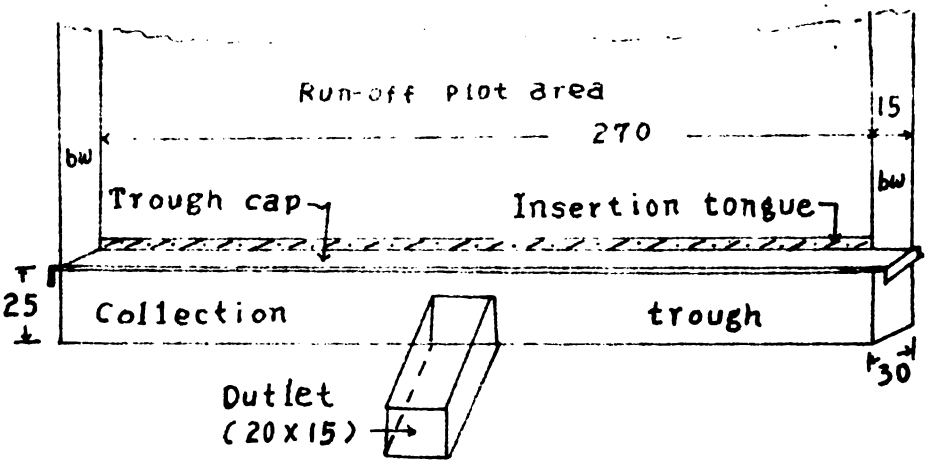


Fig. 6-1 Front view of collection trough (unit: cm)

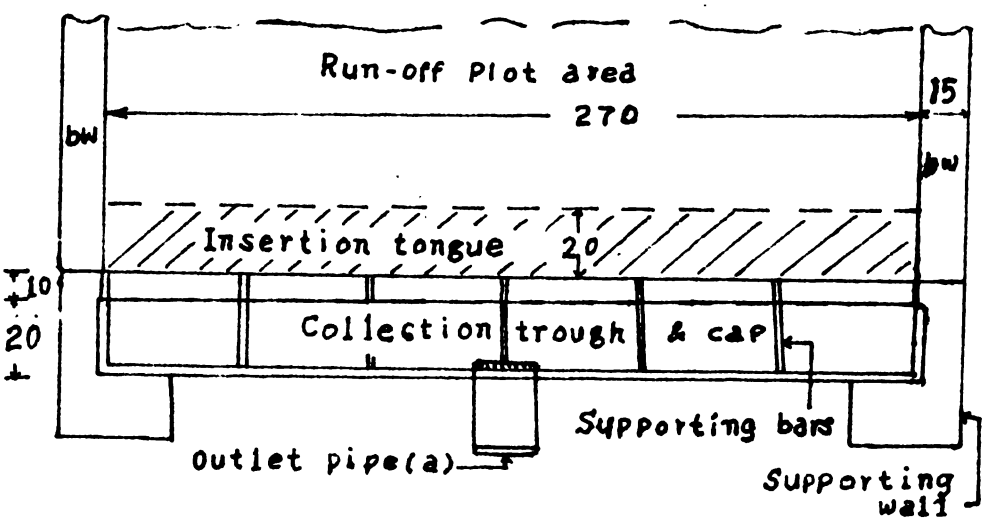


Fig. 6-2 Top view of collection trough (unit: cm)

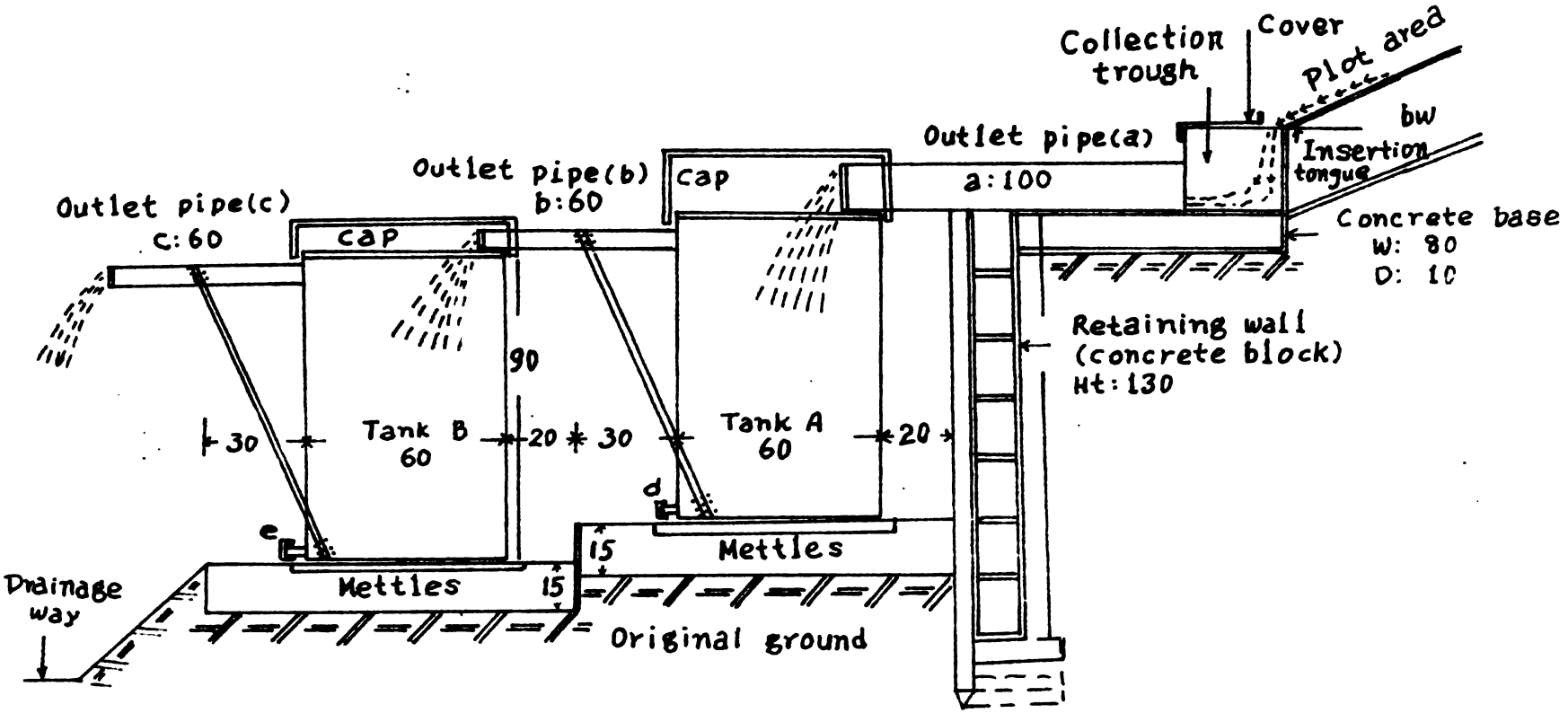


Fig. 6-3 Side view of tank A & B, outlet pipe a, b, c, d, e, trough, retaining wall, and concrete base (Unit: cm)

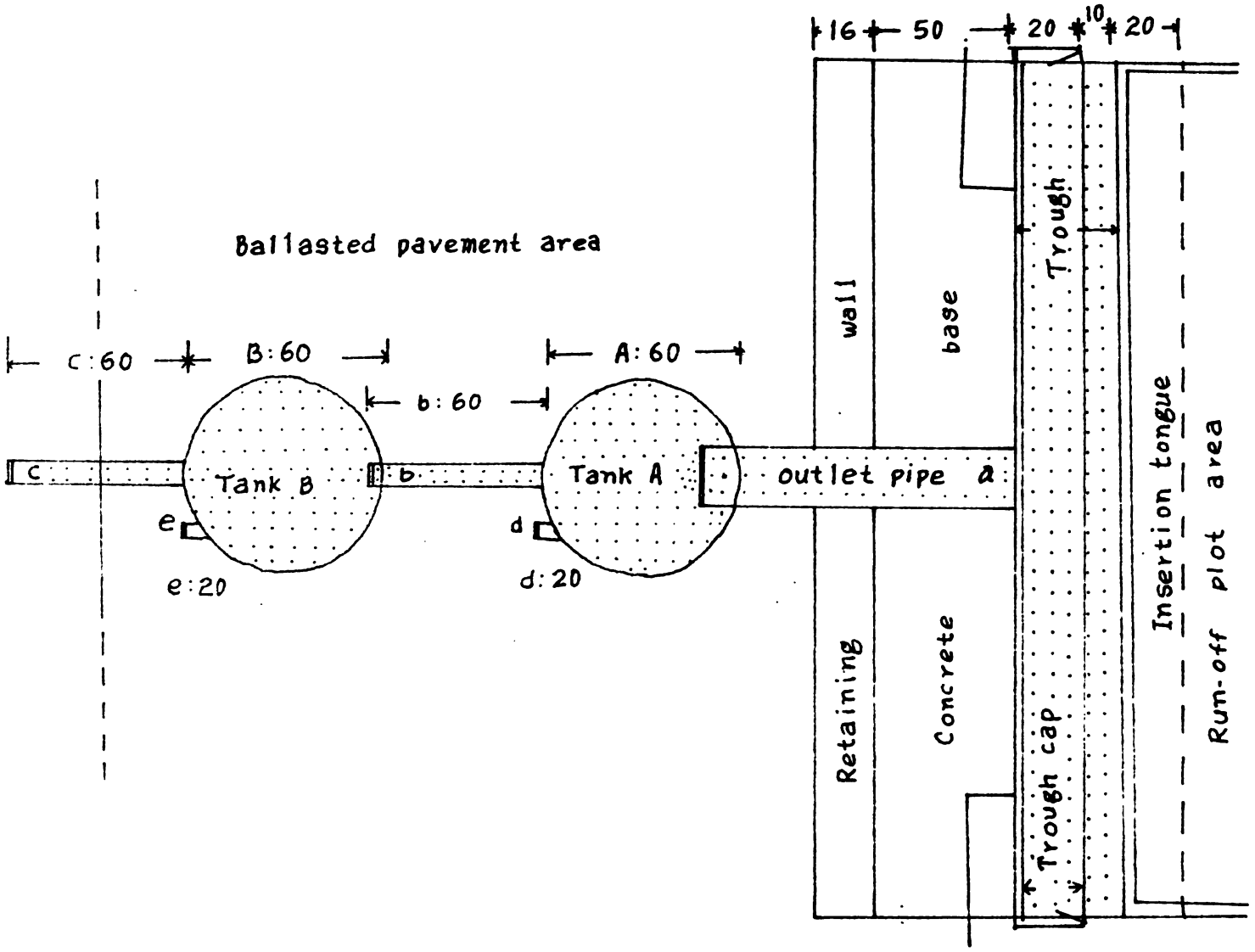
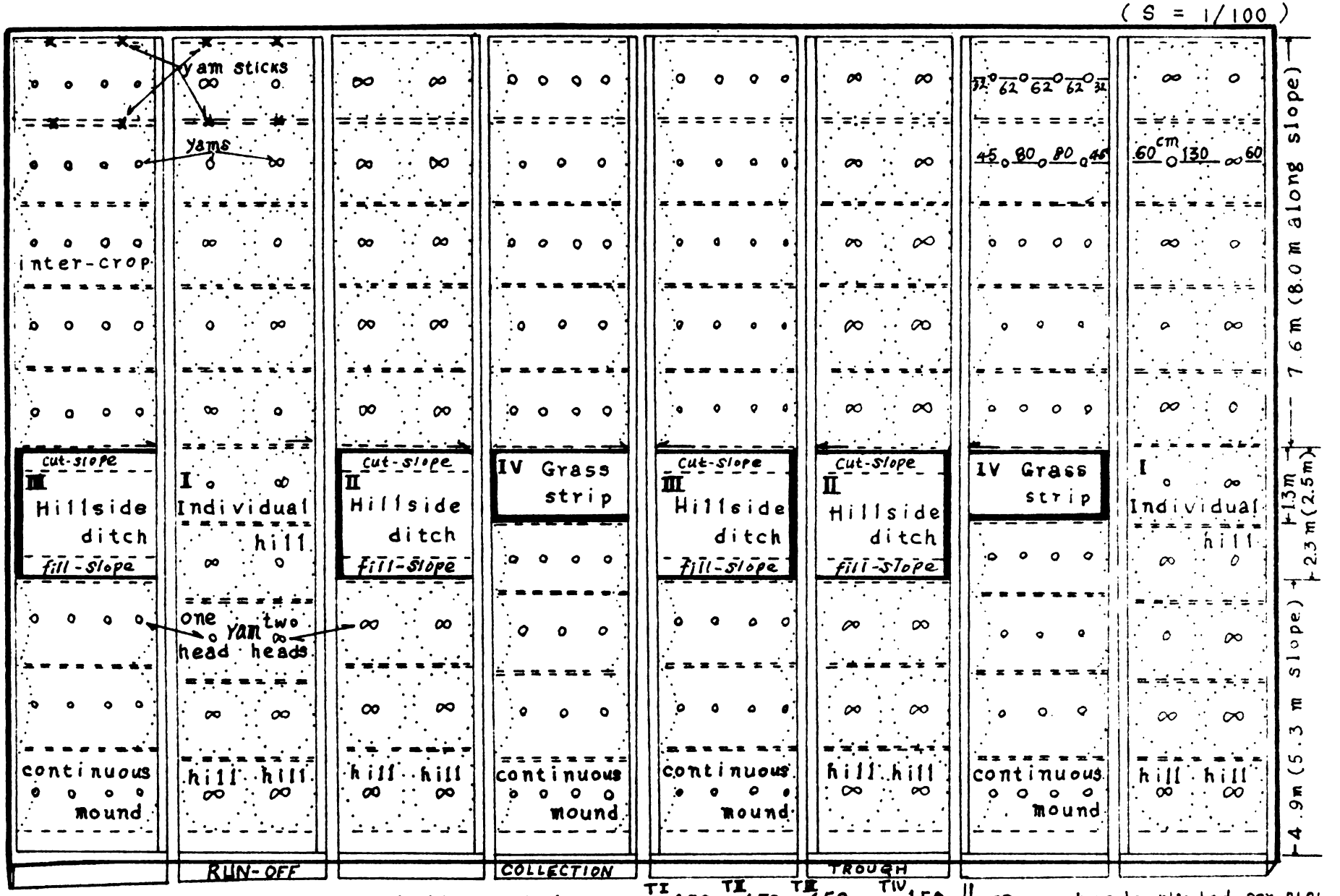


Fig.7 Top-view of tank A & B, outlet a, b, c, d, e, trough, retaining wall and concrete base (unit : cm)

Fig.8 SOIL CONSERVATION MEASURES AND CROPPING SYSTEMS IN THE RUN-OFF PLOTS



Distance between mounds & hills up & down : 150 150 150 150

Distance between yam heads horizontally (cm): 130 130 62 62; 80

32 yam-heads planted per PlOt.

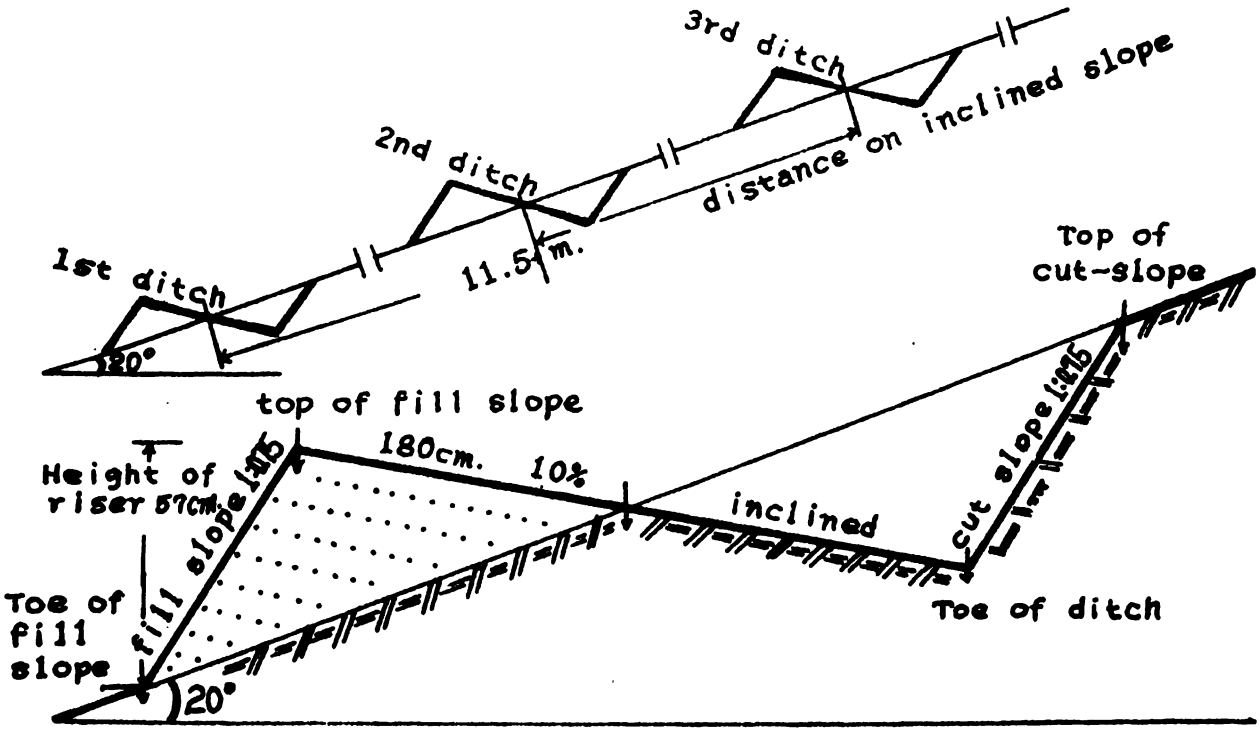


Fig. 9 Cross Section of Hillside Ditch

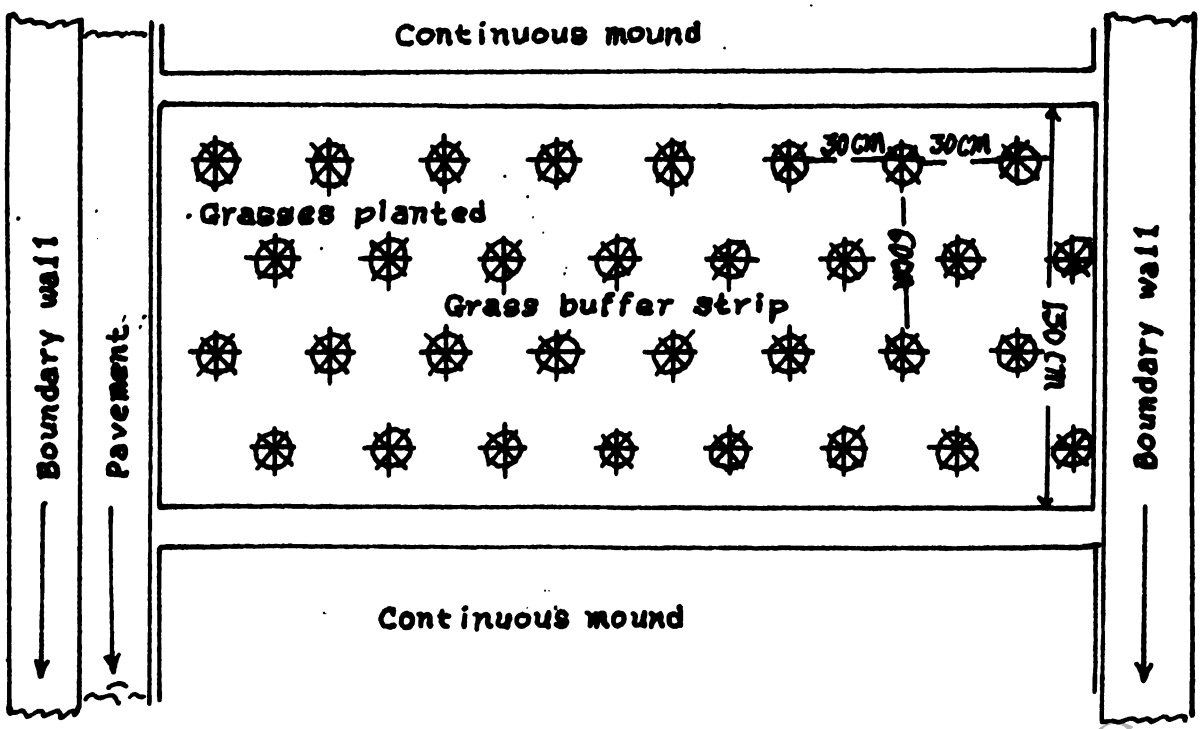
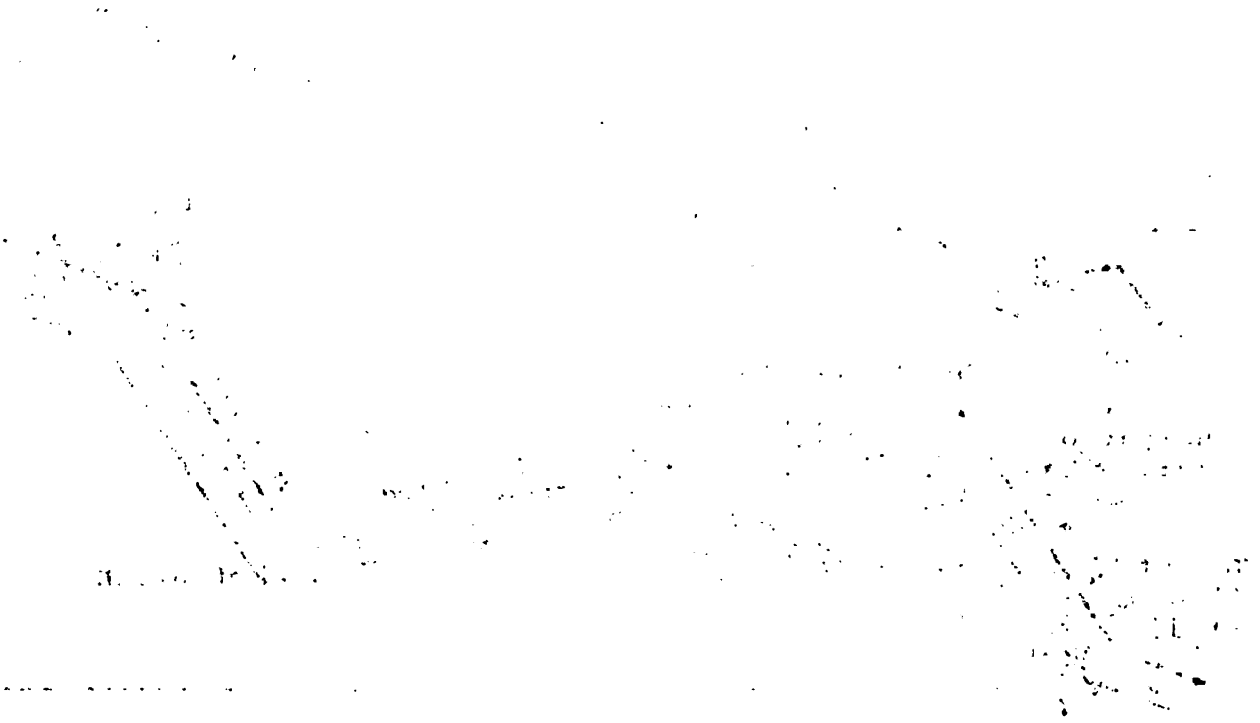
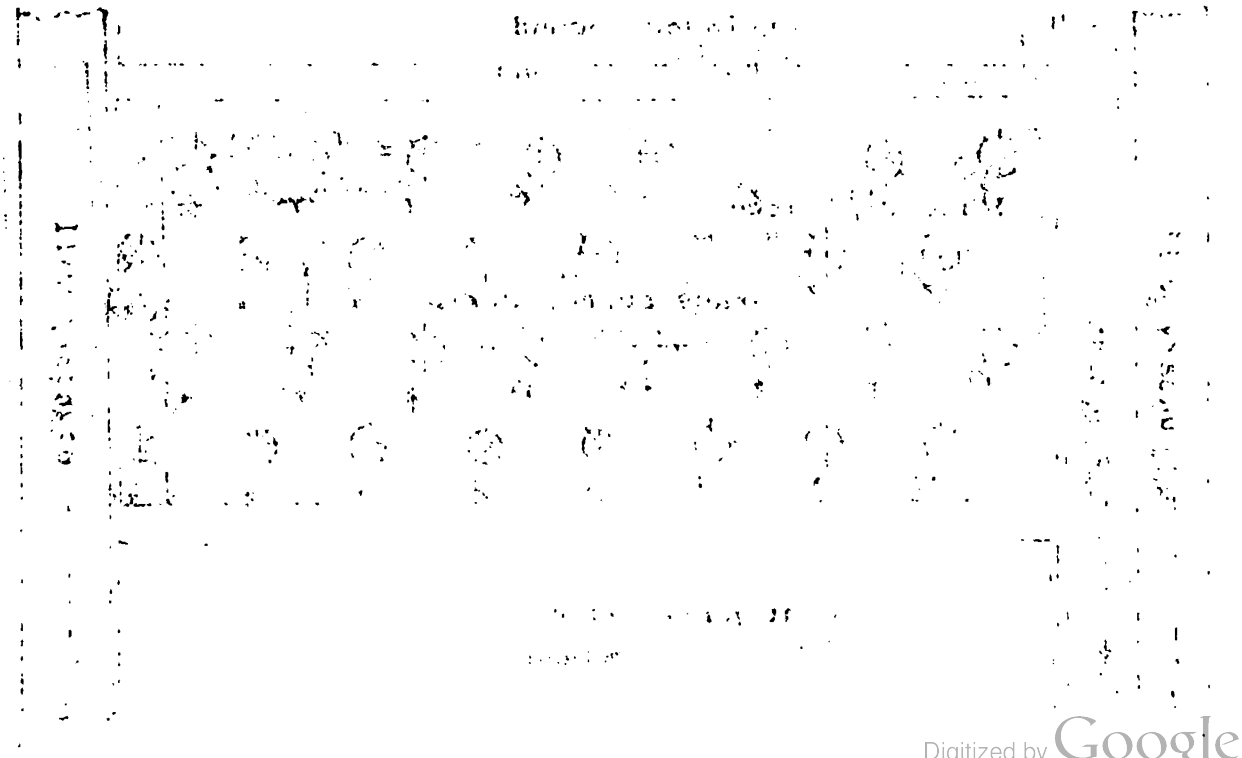


Fig.10 Plane View of Grass Buffer Strip





Annex 1

Daily rainfall (mm) recorded [illegible] Apr [illegible] 1981
at the Olive River Demon[illegible]

	1980 Apr.	May	June	July	Aug	Sept.	Oct	Nov.	1980 Dec	1981 Jan.	1981 Feb.	1981 Mar.
1		47.3	18.6	47.0	-	8.2	4.2	-	-	-	-	-
2		-	10.2	-	-	-	-	-	-	8.0	4.4	-
3		-	-	8.0	-	-	-	6.7	4.6	-	-	5.8
4		-	-	-	-	13.4	-	5.2	-	-	-	ended
5		2.1	-	13.0	116.2	-	-	6.8	-	3.2	-	
6		15.2	30.0	3.4	100.4	-	12.2	10.2	-	-	-	
7		20.0	-	-	-	-	4.8	-	-	-	-	
8		3.5	30.4	-	-	-	-	-	4.0	-	-	
9		37.4	-	42.6	-	1.2	-	9.0	-	8.0	-	
10		-	-	3.4	-	-	-	-	-	-	-	
11		-	-	8.0	12.5	6.2	-	-	-	-	7.8	
12		-	-	1.0	-	-	3.0	-	-	2.9	-	
13		1.0	-	1.0	-	-	-	-	-	-	-	
14		3.4	-	-	-	-	-	-	-	-	-	
15		3.0	-	-	6.0	6.2	-	-	-	-	-	
16		35.0	-	-	-	4.2	-	-	2.4	-	19.4	
17		-	-	-	-	2.1	6.4	13.8	8.0	-	4.2	
18		-	-	-	-	-	8.0	-	-	-	-	
19		-	-	-	25.5	-	7.0	3.2	-	-	-	
20		13.0	-	9.5	9.5	-	15.0	-	51.6	-	-	
21		-	-	-	-	13.8	20.4	-	-	-	-	
22		-	-	-	-	-	25.0	-	39.6	13.8	-	
23		-	-	-	-	-	-	-	-	5.6	-	
24		-	-	-	-	3.2	-	4.4	21.5	-	-	
25		53.0	-	-	-	-	-	-	-	-	-	
26	started	5.0	-	-	0.6	-	-	-	8.0	1.7	-	
27	-	25.3	-	-	2.0	-	-	-	-	-	-	
28	-	13.6	-	-	-	-	-	1.8	-	-	-	
29	-	37.2	-	-	-	-	-	-	4.8	-	-	
30	-	-	-	-	-	9.4	-	-	-	-	-	
31	-	17.2	-	-	-	-	-	-	-	-	-	
Total	-	332.0	89.2	136.9	272.7	67.9	106.0	61.1	144.5	43.2	35.8	5.8

Total 1295.1 mm

(Underlined dates indicate the dates on which samples were collected for soil loss determination.)

Annex 2

Monthly rainfall and number of rainy days for the period May 1980 - March 1981, at the Office of [illegible], Lower River, Ficlawny

Year	Month	Rainfall		No. of rainy days
		mm	inches	
1980	May	332.0	13.1	17
	June	89.2	3.5	4
	July	136.9	5.4	10
	August	272.7	10.7	8
	September	67.9	2.7	10
	October	106.0	4.2	10
	November	61.1	2.4	9
	December	144.5	5.7	9
1981	January	43.2	1.7	7
	February	35.8	1.4	4
	(March)	(5.8)	(0.2)	(1) (Until March 3)
Total		1,295.1	50.9	89 days

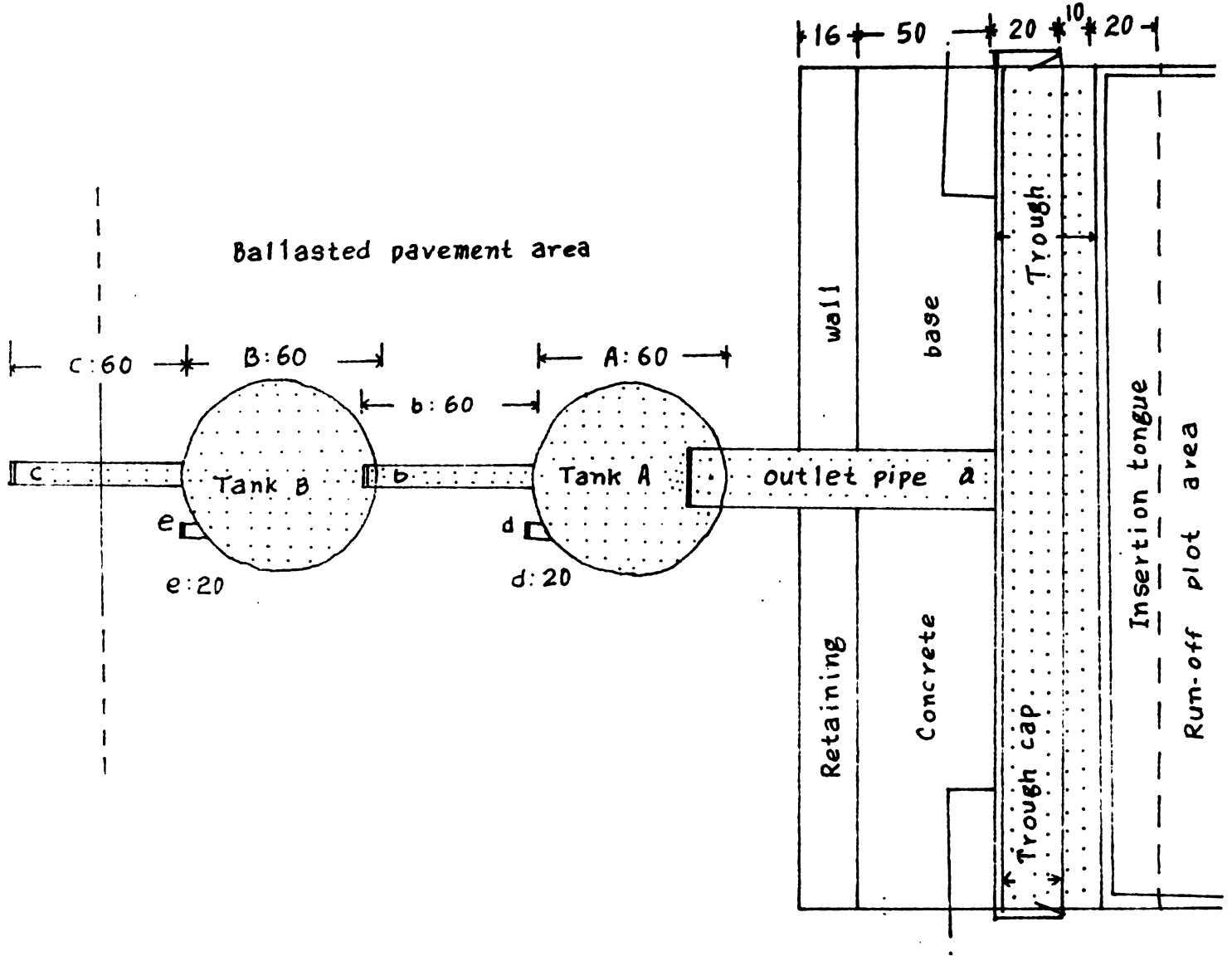


Fig.7 Top-view of tank A & B, outlet a, b, c, d, e, trough, retaining wall and concrete base (unit: cm)

Annex 4

Oven-dry weight of soil sediment from each run-off plot by sampling interval

Sample No.	Period occurred from - to	Replication, Total, Mean	Treatments (kg/plot 40 m^2)				Cumulative rainfall for the period
			Treatment I	Treatment II	Treatment III	Treatment IV	
1st	1980 April 26, May 8, (12 days)	R 1 R 2 Total Mean	109.50 44.96 154.46 77.23	51.61 57.37 108.98 54.49	28.69 17.14 45.83 22.92	20.99 27.21 48.20 24.10	(mm) 87.9
2nd	1980 May 9, May 20, (12 days)	R 1 R 2 Total Mean	184.53 165.33 349.86 174.93	89.94 97.34 187.28 93.64	45.27 39.81 85.08 42.54	33.58 34.38 67.96 33.98	92.8
3rd	1980 May 21, May 27, (7 days)	R 1 R 2 Total Mean	81.12 77.15 158.27 79.14	31.91 39.50 71.41 35.71	14.06 6.03 20.09 10.05	8.73 7.50 16.23 8.12	83.3
4th	1980 May 28, June 10, (14 days)	R 1 R 2 Total Mean	108.64 108.23 216.87 108.44	29.37 24.71 54.08 27.04	6.46 4.84 11.30 5.65	2.17 5.00 7.17 3.59	157.2
5th	1980 June 11, July 4, (24 days)	R 1 R 2 Total Mean	50.31 25.98 76.29 38.15	4.11 1.46 5.57 2.79	1.71 0 1.71 0.86	0 1.82 1.82 0.91	55.0
6th	1980 July 5, July 22, (18 days)	R 1 R 2 Total Mean	119.03 66.98 186.01 93.01	87.78 61.97 149.75 74.88	29.89 31.87 61.76 30.88	27.15 45.30 72.45 36.23	81.9
7th	1980 July 23, August 12, (21 days)	R 1 R 2 Total Mean	92.72 74.28 167.00 83.50	75.53 68.88 144.41 72.21	55.01 49.94 104.95 52.48	31.90 33.45 65.35 32.68	229.1
8th	1980 August 13, September 9, (28 days)	R 1 R 2 Total Mean	22.97 11.44 34.41 17.21	22.34 11.67 34.01 17.01	5.85 14.02 19.87 9.94	5.29 9.11 14.40 7.20	66.4

Annex 4 (cont.)

Sample No.	Period occurred from - to	Replication, Total, Mean	Treatment kg/plot 40 m^2)				Cumulative rainfall for the period
			Treatment I	Treatment II	Treatment III	Treatment IV	
9th	1980 September 10, October 7, (28 days)	R 1	35.37	20.31	10.69	11.53	66.3
		R 2	19.33	22.28	12.11	9.65	
		Total	54.70	42.59	22.80	21.18	
		Mean	27.35	21.30	11.40	10.59	
10th	1980 October 8, December 10, (64 days)	R 1	44.53	19.08	6.21	9.99	154.5
		R 2	5.04	8.90	10.77	6.95	
		Total	49.57	27.98	16.98	16.94	
		Mean	24.79	13.99	8.49	8.47	
11th	1980 December 11, 1981 March 3, (83 days)	R 1	6.02	9.68	2.93	2.62	220.7
		R 2	3.83	6.40	8.63	9.79	
		Total	9.85	16.08	11.56	12.41	
		Mean	4.93	8.04	5.78	6.21	
	Total (312 days)	R 1	854.74	441.66	206.77	153.95	1295.1 (50.9 in)
		R 2	602.55	400.48	195.16	190.16	
		Total	1457.29	842.14	401.93	344.11	
		Mean	728.65	421.07	200.96	172.08	

Annex 5

Rainfall, sampling periods and amount of soil loss from run-off plots treated with different soil conservation cum cropping system treatments at the GOJ/IICA Demonstration Centre, Olive River, Trelawny, during the 1980 - 1981 crop cycle.

Sampling interval	Sample No.	Rainfall received during sampling interval (mm)	Cumulative Rainfall (mm)	Soil conservation treatments 1/	Replicate and mean	Oven-dry soil (tonnes/ha) 2/
1980 April 26 - May 8 3/	1	87.9	87.9	1	1	27.38
					2	11.25
					Mean	19.32
				2	1	12.90
					2	14.35
					Mean	13.63
				3	1	7.18
					2	4.29
					Mean	5.74
				4	1	4.87
					2	6.80
					Mean	5.84
1980 May 9 - May 20	2	92.8	180.7	1	1	46.13
					2	41.33
					Mean	43.73
				2	1	22.47
					2	24.33
					Mean	23.40
				3	1	11.32
					2	9.95
					Mean	10.64

1/ Treatments: (1) Individual hills cropped to yam alone with no soil conservation measure; (2) individual hills with hillside ditch cropped to yam plus Irish potato plus radish plus peanuts; (3) continuous contour mounds with hillside ditch and cropped as in (2); and (4) continuous contour mounds with a grass buffer strip cropped as in (2).

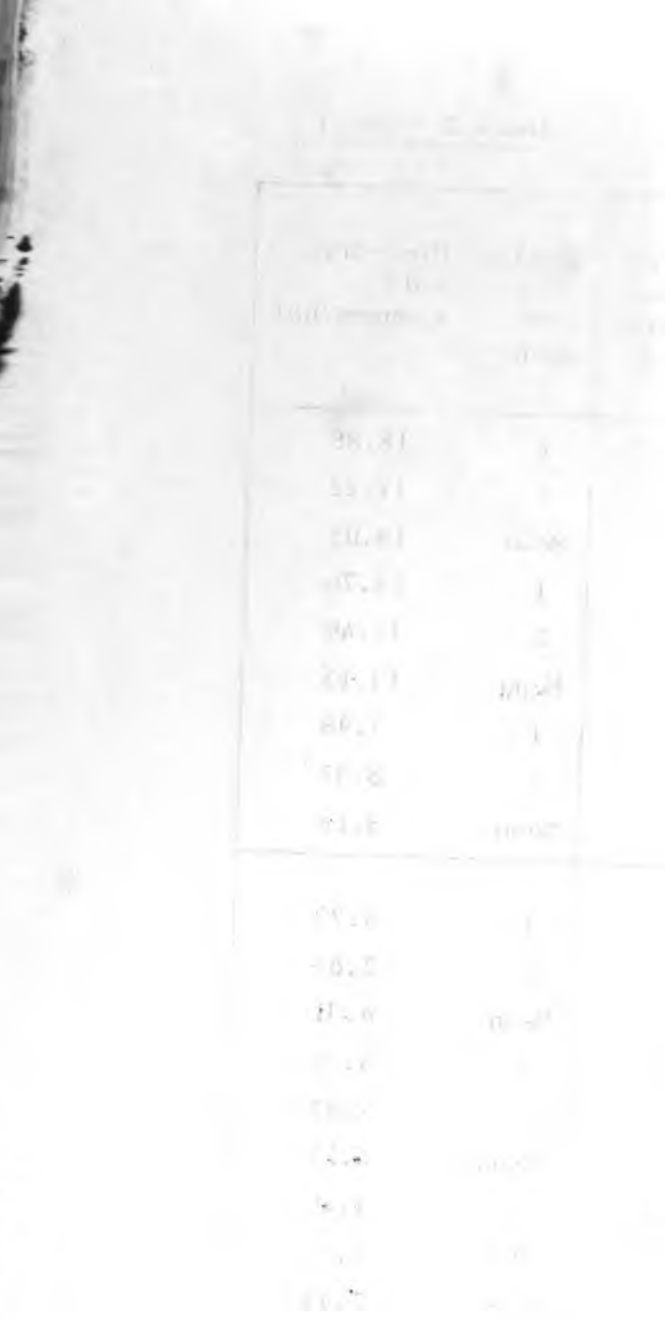
2/ 1000 kg equals one tonne.

3/ Dates inclusive.

Sampling interval	Sample No.	Rainfall received during sampling interval (mm)	Cumulative rainfall (mm)	Soil conservation treatments	Replicate and mean	Oven-dry soil (tonnes/ha)
				4	1	8.40
					2	8.60
					Mean	8.50
1980						
May 21 - May 27	3	83.3	264.0	1	1	20.28
					2	19.29
					Mean	19.79
				2	1	7.98
					2	9.87
					Mean	8.93
				3	1	3.52
					2	1.51
					Mean	2.52
				4	1	2.19
					2	1.88
					Mean	2.04
1980						
May 28 - June 10	4	157.2	421.2	1	1	27.16
					2	27.06
					Mean	27.11
				2	1	7.34
					2	6.18
					Mean	6.76
				3	1	0.64
					2	1.22
					Mean	0.93
				4	1	0.54
					2	1.25
					Mean	0.90

Sampling interval	Sample No.	Rainfall received during sampling interval (mm)	Cumulative rainfall (mm)	Soil conservation treatments	Replicate and mean	Oven-dry soil (tonnes/ha)
1980 June 11 - July 4	5	55.0	476.2	1	1	12.58
					2	6.50
					Mean	9.54
				2	1	1.03
					2	0.09
					Mean	0.56
				3	1	0.43
					2	0.00
					Mean	0.22
				4	1	0.00
					2	0.46
					Mean	0.23
1980 July 5 - July 22	6	81.9	558.1	1	1	29.76
					2	16.75
					Mean	23.26
				2	1	21.94
					2	15.49
					Mean	18.72
				3	1	7.48
					2	7.97
					Mean	7.73
				4	1	6.79
					2	11.33
					Mean	9.06
1980 July 23 - August 12	7	229.1	787.2	1	1	23.18
					2	18.57
					Mean	20.88

Sampling interval	Sample No.	Rainfall received during sampling interval (mm)	Cumulative rainfall (mm)	Soil conservation treatments	Replicate and mean	Oven-dry soil (tonnes/ha)
				2	1	18.88
					2	17.22
					Mean	18.05
				3	1	13.76
					2	12.49
					Mean	13.13
				4	1	7.98
					2	8.37
					Mean	8.18
1980 August 13 - September 9	8	66.4	853.6	1	1	5.75
					2	2.87
					Mean	4.31
				2	1	5.58
					2	2.92
					Mean	4.25
				3	1	1.46
					2	3.51
					Mean	2.49
				4	1	1.33
					2	2.28
					Mean	1.81
1980 September 10 - October 7	9	66.3	919.9	1	1	8.85
					2	4.83
					Mean	6.84
				2	1	5.08
					2	5.57
					Mean	5.33



Sampling interval	Sample No.	Rainfall received during sampling interval (mm)	Cumulative rainfall (mm)	Soil conservation treatments	Replicate and mean	Oven-dry soil (tonnes/ha)
				3	1	2.68
					2	3.03
					Mean	2.86
				4	1	2.88
					2	2.32
					Mean	2.60
1980 October 8 - December 10	10	154.5	1074.4	1	1	4.65
					2	1.26
					Mean	2.96
				2	1	4.77
					2	1.12
					Mean	2.95
				3	1	1.55
					2	2.70
					Mean	2.13
				4	1	2.50
					2	1.74
					Mean	2.12
1980 December 11 - 1981 March 3	11	220.1	1295.1	1	1	1.51
					2	0.96
					Mean	1.23
				2	1	2.43
					2	1.60
					Mean	2.02
				3	1	0.73
					2	2.16
					Mean	1.45
				4	1	0.66
					2	2.45
					Mean	1.56

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