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WATERSHEDS OF JAMAICA

AND

CONSIDERATIONS FOR AN ORDINAL SCALE

OF

THEIR DEVELOPMENT

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CONSIDERATIONS FOR AN ORDINAL SCALE OF THEIR DEVELOPMENT

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"AGRICULTURE IN JAMAICA"

Collection of papers of the Office of IICA in Jamaica.

1977 - 1978

No. I - 1 Fritz Andrew Sibbles, "Basic Agricultural Information on Jamaica Internal Document of Work." January, 1977.

No. I - 2 Yvonne Lake, "Agricultural Planning in Jamaica"., June 1977.

No. I - 3 Aston S. Wood, Ph.D., "Agricultural Education in Jamaica" , September - October 1977.

No. I - 4 Uli Locher, "The Marketing of Agricultural Produce in Jamaica", November, 1977.

No. I - 5 G. Barker, A. Wahab, L.A. Bell, "Agricultural Research in Jamaica", November, 1977.

No. I - 6 Irving Johnson, Marie Strachan, Joseph Johnson, "Land Settlement in Jamaica", December, 1977.

No. I - 7 Government of Jamaica, "Agricultural Government Policy Papers", February, 1978.

No. I - 8 Jose Emilio Araujo, "The Communal Enterprise", February, 1978.

No. I - 9 IICA and MOAJ, "Hillside Farming Technology - Intensive Short Course", Vols. I and II, March, 1978.

No. I - 10 Jose Emilio Araujo, "The Theory Behind the Community Enterprise Seminar in Jamaica", March, 1978.

No. I - 11 Marie Strachan, "A National Programme for the Development of Hillside Farming in Jamaica", April, 1978.

No. I - 12 D. D. Henry, "Brief Overall Diagnosis of Hillside Farming in Jamaica", May, 1978.

No. I - 13 Neville Farquharson, "Production and Marketing of Yams in Allsides and Christiana", May, 1978.

No. I - 14 R. C. Harrison, E. McDonald, A. H. Wahab, "Fertility Assessment of Newly Terraced Hillside Soils using the Microplot Technique, the Allsides Case Study", 1978.

No. I - 15 IICA - IDB, "Course in Preparation and Evaluation of Agricultural Projects", Vols. I and II, November 1977.

No. I - 16 Neville Farquharson, "Production and Marketing of Dasheen in Allsides and Christiana", June, 1978.

1978 - 1979

No. II - 1 O. Arboleda-Sepulveda (IICA-CIDIA), "Agricultural Documentation and Information Network in Jamaica", (Elements for a Proposal)

No. II - 2 Victor Quiroga, "National Agricultural Information System", (NAIS - Jamaica) Project Profile, September 1978.

No. II - 3 Joseph S. Johnson, "A Review on Land Reform in Jamaica for the Period 1972 - 1978", September, 1978.

No. II - 4 Neville Farquharson, "ABC of Vegetable Farming: A Draft High School Textbook", Volumes I, II, III, and IV. February, 1979.

No. II - 5 Jerry La Gra, "Elements of an Agricultural Marketing Strategy for Jamaica", March 1979.

No. II - 6 D. D. Henry and I. E. Johnson, "Agricultural Extension Service in Jamaica", March, 1979.

1979 - 1980

No. III - 1 H. R. Stennett, "Watersheds of Jamaica and Considerations For An Ordinal Scale of Their Development", July 1979.

F O R E W O R D

IICA in Jamaica has been sponsoring a number of background papers, of which the present one is the latest. Research and Transfer of Agricultural Technology for the Hilly Watersheds of Jamaica is one of IICA's interest for promoting the improvement of the institutional system of the rural sector. In 1977 work began in collaboration with the Ministry of Agriculture's counterparts to carry out fundamental research in the first instance in the Martha Brae Watershed, at the locality of Allsides. At the same time training was given by the IICA technicians at the counterpart levels in research methods, management and the new systems of production for newly terraced lands. These were carried out on the site.

Although the new cropping systems research, which shows a promise of increasing the farmers' income, has not yet been completed, farmers are showing interest, and extension involvement is being stepped up to involve farmers in the programme, construction of terraces, social organizations, etc.

For the purpose of understanding the present situation, and assisting the small farmers IICA is interested in Regional Rural Development on a Watershed basis. To promote this IICA Jamaica has pursued various activities, among which we can mention:

1. Pursuing research in soil conservation and new technologies in hillside food production;
2. Investigating the optimum soil treatments for greater productivity;
3. Investigating the prices and demands of various crops, time of planting, specific cultivators, eg., to test disease resistance so as to determine rotations, multiple cropping systems, agronomic practices in management of the technical package which should be adopted. Very little research has been carried out in Jamaica on small farms and specifically on hillsides;

4. To assess the economic returns within the soil conservation system which takes into consideration the maintenance and improvement of the soil resource, not only by the addition of organic and inorganic manures, but also by the economical use of the nutrients through the correct selection of crop;

5. The experimentation of introducing small stock (goats) and even a heifer, so as to maximise resources, e.g. use of grass from risers as fodder;

6. The marketing system is being investigated so as to ensure the possibility of a secure market for the crops, whenever possible locally. Additionally, legume trials are aimed at producing adequate or supplementary protein so that the nutrition of the community is being taken into consideration; and

7. The promotion of Jamaican publications on agriculture, which will provide an up-to-date assessment of the sector and alternatives for achieving improvement of the sector. The collection of IICA papers "Agriculture in Jamaica" already comprises twenty-three titles and twenty-eight volumes, of which the present volume <u>Watersheds of Jamaica</u> by Henry Stennett is considered a worthy addition.

Mr. Henry Stennett, Director of the Soil Conservation Department of the Ministry of Agriculture, is an experienced technician and one of the best sources of information on the subject. We are happy to present his paper as another effort of IICA/Jamaica to gather up-to-date, useful information for the agricultural sector.

Dr. Percy Aitken-Soux
IICA/Jamaica Director

<u>July, 1979</u>

ABSTRACT

This paper attempts to present some background information on Jamaica's watersheds and reviews briefly the problems associated with them. The paper stresses the peculiar problems brought about by the cultivation of agriculture on marginal hilly lands, under improper or inadequate soil conservation measures, which as it is expected, are resulting in serious soil losses throughout, extreme degrees of erosion, siltation and sedimentation problems.

The major problems associated with the above are the rapid and widespread deterioration of the nation's soil resources and the impairment of its water quality.

The report reviews the criteria used in the classification of the country's watersheds and has set out an ordinal scale for the First and Second priority groups.

Chapter Three provides some information on the watersheds, such as physical features, geology, land forms and soils, climate, rainfall, socio-economic conditions, population and land tenure.

Finally, the author has included a short manual on management of Jamaica's watersheds in Chapter Four, designed to provide information on the protection of cultivated slopes in humid tropical countries such as Jamaica.

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INTRODUCTION AND BACKGROUND

1.1. INTRODUCTION:

It has been recognized, since very early times, that there exists an intimate relationship between land and water and that the method of managing the land has a direct bearing on the amount and rate of runoff as well as on the quality of stream flow. An ancient Chinese saying says that "he who rules the mountains rules the rivers".

Watershed management is primarily dealing with the protection, conservation and development of water resources in the upstream regions. Its main objectives are:

(a) to maintain and increase water quantity;
(b) to regulate the timing of streamflow;
(c) to minimize erosion and sediment hazards;
(d) to maintain or improve water quality; and
(e) to reduce flood damage.

Management of the land to benefit the water resources may include manipulation of the microclimate, vegetation, soil topography, animal life and in some small degree even the geology.

Generally, watershed management can be divided into the following categories:

(a) watershed protection;
(b) watershed rehabilitation; and
(c) watershed improvement.

Watershed protection is needed where the watershed is good, is in a stable equilibrum, and where protection is required to avoid damages. Watershed rehabilitation is required in deteriorated watersheds while watershed improvement is for improving the flow regime or water yield.

As water problems become more acute in Jamaica, the need for proper and scientific watershed management becomes imperative.

In Jamaica, industrial growth, the rapid rate of urbanization and the increase in population is making greater and more exacting demands on our land and water resources. One direct effect of all this is that more roads are being constructed in the mountainous areas, more sloping lands are being framed and more houses and factories are being constructed in the upstream of our watersheds resulting in serious deterioration in the water quality of our streams and rivers.

1.2. BACKGROUND:

1.2.1. Watershed problems of Jamaica

Awareness of soil erosion and the subsequent problems and hazards are not new to Jamaica. As early as 1937, Croucher and Swabey, in their article entitled "Soil Erosion and Soil Conservation in Jamaica," 1937 emphasized the chief causes of soil erosion in Jamaica as:

(a) unsuitable agricultural practices;
(b) unwise selection of land for agriculture; and
(c) lack of appreciation for the seriousness of the problem.

During the evaluation studies carried out by the UNDP/FAO Forestry/Watershed Management Project in 1972 soil erosion and sedimentation were identified as the major watershed problems in Jamaica. Erosion has been the chief cause of the low productivity of hillside lands in Jamaica. This productivity has continued to fall at an alarming rate and there is dramatic deterioration in soil and water resources. This rapid rate of sedimentation has often hampered water resource development in some watersheds since that portion of the total storage capacity which has to be reserved to allow for siltation in a reservoir presents a severe constraint on the economics of such projects.

Two major sources of erosion and sedimentation are identified as follows:-

(a) the cultivation of sloping lands without proper soil conservation practices; and
(b) the construction of roadways in mountainous terrain.

1.2.2. Socio-Economic Problems

The many socio economic problems of our watersheds may be enunciated as follows:-

(a) The island of Jamaica consists predominantly of hilly lands and only twenty percent of the land can be regarded as flat or gently sloping. Most of these hilly lands are occupied by over 200,000 small farmers who cultivate less than five acres of these lands and who practice a system of shifting cultivation coupled with clean farming practices.

    The intensive cultivation of these marginal lands coupled with tropical rainfall of high intensity without proper soil conservation practices has resulted in severe erosion problems.

(b) The unemployment rate in most of the watersheds is high and for sometime has been officially estimated to be in the region of 20 - 25 percent. The highest unemployment rate is always among the youthful population.

(c) There is still a net rural to urban migration and at the present time close to 40 percent of the country's population live in the towns and cities. This trend can be expected to continue or even accelerate if present conditions in the watersheds are not made sufficiently attractive and drastic improvements made.

(d) Not enough of the young people are engaged in agriculture although the other sectors of the economy cannot easily absorb them.

(e) Over the past years the production of domestic food crops has increased considerably due to the efforts and achievements of such government schemes as Project Land Lease and the Emergency Production Programme. Unfortunately, however, the performance of the major export crops has been disappointing and some have even showed a sharp decline. While the reasons for the abovementioned situation may be many, a major reason is deterioration of the hilly land resources on which a fair proportion of these export crops are grown without the appropriate soil conservation measures.

(f) The food import values remain high despite the creditable performance of domestic production due mainly to such causes as the devaluation of the Jamaican dollar.

1.2.3. Watershed Management Activities in Jamaica

Early in 1951, the Government enacted the Land Authorities Law. Two Land Authorities, the Yallahs Valley and Christiana, were established during that decade and in 1969 a further eleven Land Authorities were created, under the Ministry of Rural Land Development. The physical boundaries of the Authorities tended to follow the major watershed divides. Following the change of Government in 1972, the Land Authorities were incorporated in the Ministry of Agriculture. In 1963 the Government promulgated the Watershed Protection Act, under which the Watersheds Protection Commission was established the same year.

The Act and the Law are similar, providing the Government with the power of declaring watersheds or areas for rehabilitation and improvement. The respective administration is empowered also to implement compulsory land improvement schemes as well as to assist with any rehabilitation work within the declared boundaries.

According to the Watersheds Protection Act, 1963, the general policy of watershed protection and rehabilitation is 'to promote the conservation of water resources'. This has been interpreted by the Watersheds Protection Commission as follows:

(a) Maintain and, if possible, increase the quantity of water available;
(b) Minimize erosion and sediment hazards; and
(c) Reduce flood damage.

The Watersheds Protection Commission was incorporated into the National Resources Conservation Department in 1974. This Department now administers the Watershed Act. The Land Authority Law is slightly different in objective although the work programme may be similar to that stipulated in the Watersheds Protection Act. The Law is rather land-oriented, i.e. improvement, rehabilitation and development of the area, and aims to 'encourage and secure the proper economic and efficient utilization of all lands in the declared area'. The Land Authority is more production oriented while the Watersheds Protection Act tries to secure protection for water benefits.

The Government has, to date, declared seven watersheds, totalling 152,000 ac: Appendix 1.

DECLARED WATERSHEDS IN JAMAICA

Watershed	Acreage	Date Declared
Cane River, St. Andrew	6,400	11 February 1964
Rio Minho, Clarendon	21,700	11 February 1964
Rio Nuevo, St. Mary	24,000	11 February 1964
Rio Pedro, St. Catherine and St. Andrew	20,100	14 February 1967
Lucea/Cabaritta, Hanover and Westmoreland	21,100	14 February 1967
Negro/Johnson, St. Thomas	32,600	4 December 1968
Roaring River, Westmoreland	26,100	4 October 1972
Total:	152,000	

Note: The watershed boundary may not always follow a natural divide.

Recently two other watersheds, Two Meetings Watershed having 9,992 acres and Pindars River Watershed having 19,192 acres, were declared on the recommendation of the USAID/GOJ Integrated Rural Development Project.

Beginning with the Yallahs Valley and Christiana Area Land Authorities, watershed rehabilitation work in Jamaica now spans more than a quarter of a century. However, during the first decade, knowledge and experience were limited. Considerable sums of money were spent in the two Land Authorities with only partial success in physical rehabilitation or in the rationalization of land use due mainly to the fact that most of the treatments used were too temporary to have lasting benefits.

In more recent times, limited funds and a handful of trained personnel have been spread thinly throughout the seven declared watersheds and the thirteen Land Authorities. The impact of rehabilitation work has, therefore, been insignificant.

Between 1969 and 1975 a UNDP/FAO project assisted the Government in setting up small demonstration sub-watersheds on public lands, and in personnel training. Major rehabilitation techniques are now available and about 160 agricultural officers, assistants and headmen have been trained in this particular field. In 1973 the Government resuscitated the Soil Conservation Unit within the Ministry of Agriculture. The Unit has concentrated on training of personnel for soil conservation work, establishing demonstration areas, and developing soil conservation projects and programmes. The Unit succeeded in treating an estimated 7,000 acres of land during the period 1974 - 1978.

1.2.4. <u>Systems of Production for Newly Terraced Lands</u>

From 1975 Jamaica became a member of the Inter-American Institute of Agricultural Sciences (IICA) and in 1976 signed the Agreement for its first project with IICA. The project (Allsides Pilot Development Project) was aimed at developing crop technologies best adapted to newly terraced lands. The Project was to have a duration of three years in its first stage.

The development of systems of production for newly terraced lands was the necessary step to complement the soil conservation measures initiated by the Ministry of Agriculture.

Some of the expected results of IICA's research work in the Allsides Pilot Project, among others, are:

- greater quantity of food production per unit of hillside farmed;
- better quality of production;
- import substitution;
- conservation of natural resources;
- improvement of soil resources;
- better income and standard of living for hillside farmers; and
- simple efficient technology adapted to food production and soil conservation for hillside farmers.

CHAPTER 2

CLASSIFICATION OF JAMAICA'S WATERSHEDS

2.1. WATERSHEDS OF JAMAICA

There are 33 major watersheds in Jamaica. Many of them are situated on the limestone areas of the country, while the others are located on the shales, conglomerates and tuffs deposits (Appendix 4). They show varying degrees of disturbance by man, by nature or by a combination of both. The location of watersheds and the degree and nature of past disturbances will dictate priorities for protection, rehabilitation or improvement.

The list below identifies the 33 watersheds of Jamaica and gives their respective acreages.

WATERSHEDS IN JAMAICA

Watershed No.	Name of Watershed	Approximate Acreage (Acre)	Remarks
1	Northwest Coast	99,000	Partly declared 1/ Watershed
2	Great River	100,200	
3	Reading	12,200	
4	Montego River	59,000	
5	Martha Brae	162,000	
6	St. Ann	311,600	
7	Moneague	98,200	
8	Rio Nuevo	29,000	Partly declared Watershed
9	Oracabessa	36,100	
10	Fosters Cave	6,000	
11	Water Valley	17,000	
12	Wag Water	62,000	

1/ Declared under Watersheds Protection Act.

Watershed No.	Name of Watershed	Approximate Acreage (Acre)	Remarks
13	Buff Bay River	112,000	
14	Rio Grande	66,000	
15	Northeast Coast	67,300	
16	Plantain Garden	46,000	
17	Port Morant	26,000	Partly declared Watershed
18	Morant River	47,000	
19	White River	12,000	
20	Yallahs Town	8,000	
21	Yallahs Valley	44,200	
22	Cane River	18,200	Partly declared Watershed
23	Hope River	19,000	
24	Liguanea	29,000	
25	Fresh River	22,300	
26	Rio Cobre	158,000	Partly declared Watershed
27	Salt Island Creek	65,000	
28	Coleburns Gully	44,300	Partly declared Watershed
29	Rio Minho	430,000	Partly declared Watershed
30	Bull Savanah	66,000	
31	Black River	378,200	
32	Cabaritta River	155,000	Partly declared Watershed
33	New Savannah River	17,400	Partly declared Watershed

Sources: (1) Handout material of the Seminar on Development and Use of Jamaica's Water Resources, 1968.

(2) Kaul, S.N., 1971, Agronomic Considerations (Jamaica) Technical Report 1, JAM 6.

2.2. PROCEDURES OF IDENTIFICATION OF CRITICAL WATERSHEDS

Step 1: Airphoto Interpretation

Using existing NASA 1971 infra-red transparencies and prints (scale 1:50,000), a country-wide study was undertaken of the physical conditions and disturbance of the lands. It included the identification of limestone and non-limestone areas, the kinds and degrees of disturbance, the land forms and river types, the broad vegetation types, road density and erosion forms. For a total of 320 airphotos of the non-limestone area, each photo was given a series of symbols to describe the area qualitatively.

Step 2: Identification of Location

The boundaries of those lands, identified above as severely disturbed by man and/or nature, were transferred first to the 1:50,000 topographic maps and then reduced to a 1:250,000 scale map on which the island's 33 watersheds were marked according to the decision made by the "Seminar on Development and Use of Jamaica's Water Resources, 1968". The areas were originally differentiated by colour: red indicating mainly man-made; blue indicating mainly natural, and a mixture of red and blue strips: both causes. Eighteen (18) watersheds were identified as having severely disturbed areas. The areas disturbed are mostly upstream and the proportion in a whole watershed ranges from a small amount to over 90 percent. (Appendix 3)

Step 3: Establishment of Priorities

The copies of the above-mentioned maps with the information on the severely disturbed areas were given to the National Water Authority, the Water Commission and the Ministry of Health and Environmental Control for them to locate their existing water intakes and proposed dam sites to show the relationship of the severely disturbed watersheds (sub-watersheds) to the downstream interests, indicating protection or rehabilitation needs.
Field trips were then made to observe general conditions of those

critical watersheds including topography, land use and potentials, erosion, sedimentation and accessibility. After consultations with the then Agricultural Planning Unit on the criteria to be adopted, a priority list was prepared. Additional information was collected for the five first-priority watersheds including population, registered idle lands, Government priorities, crop suitabilities and the availability of maps and large scale airphotos for future detailed planning.

2.3. ORDINAL SCALE OF WATERSHEDS

With limited budget and personnel, the question of which watershed is to receive first attention is always important. Out of the eighteen disturbed watersheds, five watersheds or sub-watersheds were classified as first priority, and the other five as second priority. The names, locations and extents are shown in the following table and total approximately 250,800 acres. This islandwide evaluation study of the country's watersheds also revealed that there are approximately 410,000 acres of land in urgent need of rehabilitation and protection. Of this, about 250,000 acres is regarded as critical and require priority treatment. These are the areas listed as first and second priority watersheds. The table also shows a further 156,800 acres which urgently require watershed management and soil conservation activities.

CRITICAL WATERSHEDS IN JAMAICA

Priority Rating	Name of Watershed, Sub-Watershed or Area	Estimated Acreage	Remarks
First Priority	Rio Pedro, in Rio Cobre	20,100	
	Pindars River, in Rio Minho	19,200	Planning Completed for Development
	Hope River	13,000	
	Yallahs Valley	30,000	
	Two Meetings at Christiana	10,000	Planning Completed
	Sub-Total	92,300	
Second Priority	Wag Water	47,700	
	Upstream area of Rio Minho	41,700	Not including Pindars River Watershed
	Lucea River, Northwest Coast	17,000	
	Upstream area of Cabaritta	6,000	
	Negro River, in Morant River Watershed	26,900	
	Upper Rio Grande at Alligator Church in Rio Grande	19,200	
	Other Sub-Total	158,500	

OTHER SUB-WATERSHEDS URGENTLY REQUIRING SOIL CONSERVATION WORKS

Black River (South Trelawny & North Manchester)	10,400 acres
St. Ann (South Trelawny)	5,000
Cane River	12,000
Rio Minho	46,800
Northeast Coast	10,000
Rio Grande	10,000
Buff Bay River	15,000
Plantain Garden	10,000
Morant River	10,000
Montego River	20,000

Great River		10,000
	Total:	159,200
	G/Total:	410,000

In 1974 the Ministry of Agriculture approved three watersheds in the first priority group for rehabilitation planning; after examination of information on degree of disturbance, downstream interests and potential for agricultural development.

These were:- Hope Watershed
Two Meetings Watershed and
Pindars River Watershed.

Since that time a plan of development has been prepared for the Two Meetings and Pindars River Watersheds; the implementation of which is being financed jointly by the Government of Jamaica and the United States Agency for International Development.

As funds and enough trained personnel become available other watersheds will undergo detailed planning for implementation of development programmes.

Supporting data for the five watersheds of the First Priority Group is set out in the tables which follow:

Name of Watershed	Watersh Area 1/
Rio Pedro	20,100 aq (Above pro posed Harkers Hall Dam, 1/3 in St. Cath- erine, 2/3 in St Andrew)
Pindars River	21,000 a (Above p posed Lucky Valley 1/6 in Catheri & 5/6 i Clarendo

1/ Also see 1:

2/ 1970 figure

Name of Water Shed	Watershed Area	Major Towns/ Villages	Erosion & Sedi- mentation	Downstream Interests
Hope River	13,000 ac (Above water in- take, all in St. Andrew)	Gordon Town, Irish Town, Guava Ridge, Mary- land.	Erosion Severe, many land- slides along roads and new housing sites	Municipal water supply
Yallahs River	30,000 ac (Above pro- posed di- version dam at Middleton Abbey. 1/2 in St. Andrew & 1/2 in St. Thomas)	Mavis Bank, Guava Ridge, Windsor Forest, St. Peters, Hagley Gap, Ramble	Very sev- ere. ero- sion. Very heavy sed- imentation	Municipal water supply mainly
Upper Cave Valley	10,600 ac (Above 2 Meetings, 1/3 in Manchester 1/3 in Clarendon 1/3 in St. Ann & Trelawny)	Christi- ana, Spald- ings, Coley- ville, Alston	Erosion severe, sedimen- tation heavy	Municipal water supply

the lands are heavily dissected by erosion. The interior mountain range appears as a window in the limestone formation.

Agricultural Development Potential

Population	Major Soil Types	Topography	Land Potentials	Idle Lands & Govt. Properties	Crops	Road Accessability	Map Availability	Availability of Air Photos
,356	Valda Gravelly Sandy Loam No.52 & Cuffy Gully Gr. Sandy Loam No. 38	Mostly very steep slopes moderately dissected	Very small portion cultivable. Mostly suitable for forest & tree crops	No registered idle lands, Water Comm. controls 2488 ac & about 800 ac was planted to trees	Coffee, Ackee, Mangoes, Vegetables Carib Pine	Good	1:5,000 50 ft contours	1970 JAM 505 1:15,000 panchromatic
,258	Valda Gr. Sandy Loam, No.52 Hall's Delight Channery Clay Loam No.46	Mostly very steep slopes, heavily dissected	Small portion cultivable. Most suitable for forest & tree crops	1104 ac registered idle lands incl. immediate below dam site. No. big Govt. prop.	Coffee, Red Peas, Pidgeon Peas, other vegetables, Mangoes Carib Pine	Fair	1:5,000 50 ft contours	1970 JAM 505 1:15,000 Panchromatic
,320	Wirefence Cl. Loam No.32 & Donnington Gr. Loam No. 36	Moderate slopes, moderately dissected	Mostly cultivable	no registered idle lands, no big Govt. properties	Bananas, Irish Potatoes, White Yams, Negro Yams, vegetables	Very good	1:5,000 — 10ft contours coverage 20%. 1:12,500 50ft/25ft contours 30%	1973 JAM 505 1:10,000 panchromatic covering 80% 1968 1:25,000 panchromatic 20%

CHAPTER 3

RELEVANT INFORMATION ON JAMAICA'S WATERSHEDS

3.1. PHYSICAL FEATURES

3.1.1. Total Area and Topography

Jamaica is situated between north latitude 17° 45' and 18° 30', and west longtitude from 76° 15' to 78° 30'. It has a maximum length of 146 miles from east to west and has varying widths north to south from 22 to 51 miles. The total area is 4,411 square miles. Eighty (80) percent of the entire country is rugged and the lands which exceed 20° slope comprise 51% of the island. Consequently, most of the island's watersheds in the upland areas are composed of steep slopes.

3.1.2. Geology, Land Forms and Soils

This island can be generally divided into three major geomorphic zones as follows: (Appendix 4)

(a) The interior mountain ranges: These form the backbone of Jamaica and are the most rugged. The highest peak is in the east where the Blue Mountains attain a height of over 7,000 feet. The central and western sections are much lower, but with several peaks over 3,000 feet. Geologically, they are composed of shales, conglomerates and tuffs, and volcanic rocks intruded at various points. In the Blue Mountain region the soils are thin and the slopes are very steep, whereas in the middle and western part, the slopes are gentler and soils deeper but the lands are heavily dissected by erosion. The interior mountain range appears as a window in the limestone formation.

(b) The limestone plateau and hills: These cover almost two-thirds of Jamaica. Except for the Cockpit type of topography, the slopes are mostly gentle and rolling. Intense faulting or fracturing of the rocks is common. Some of these faults represent considerable earth movements of land creeps. Generally speaking, the soils are thin and drainage good.

(c) The coastal plains: These plains are broader on the south and much narrower on the north side. They are mostly adjacent to limestone areas, consisting of alluvial deposits and here most of the rich cultivable lands are to be found. The majority of the plains are not really flat, having several degrees of slope and here soil erosion does constitute a problem although this is not generally recognized.

3.1.3. Climate and Rainfall

With a tropical and sub-tropical climate, Jamaica enjoys a year round growing season for the most part. Warm temperatures, high rainfall and humidity produce lush vegetation almost everywhere, except in the south during the dry season.

The average annual rainfall is about 77 inches ranging from 40 inches in some coastal areas to 300 inches or more in the north-east mountains (Appendix 5). Monthly distribution is uneven and rainfall intensities are extremely high. Jamaica has created several world records of point rainfalls in 15 minutes, and two to six days respectively. The following is an estimate of peak rainfalls and return periods from one location in the southeast of Jamaica (Vickers, 1968).

INTENSITIES OF PEAK RAINFALL (IN INCHES) FOR SPECIFIED DURATIONS AND FREQUENCIES OF OCCURRENCE FOR ONE LOCATION

Return Period	1 yr.	5 yrs.	10 yrs.	25 yrs.	50 yrs.
30 minutes	1 ¼	2	2½	2 3/4	3¼
1 hour	1 3/4	2 3/4	3¼	3 3/4	4¼
6 hours	3	4 3/4	5½	6½	7¼
12 hours	3½	5 3/4	6 3/4	8	9
24 hours	4	6 3/4	7 3/4	9	10¼

3.2 SOCIAL AND ECONOMIC CONDITIONS

3.2.1. Population

The total population of Jamaica, released in June 1978 was 2,100,000 persons. The density is about 420 persons per square mile. According to a projection made by the Central Planning Unit, the population will be about 2,671,800 in the year 1990 or an increase of 571,800 persons in twelve years time. About 40% of the present population is concentrated in the Kingston Metropolitan Area and thirteen other main towns. In 1990 this will increase to over 50% of the population. For population distribution in the watersheds, see appendices 6 and 7.

3.2.2. Labour and Unemployment

The exact rate of unemployment in Jamaica is not known, but the estimation is in the range of 25 percent.

The number of persons unemployed from the total labour force was last estimated by the Government at 203,000. The labour force projection in the year of 1990 made by the Central Planning Unit is 1,100,000 which is an increase of 317,500 persons or 40% over the present labour force. Creating job opportunities is therefore a most depressing problem facing the nation.

Agriculture engages approximately one-third of the present labour force. The tendency today is for the young people to leave the rural areas for the metropolitan centres. While industrial, mining and tourist sectors could absorb a limited labour force and the cost of training and investment per capita is expensive [1/]; the opportunities of maintaining a high level of employment in the rural areas at this stage are essential and should, therefore, not be overlooked.

3.2.3. Land Tenure

The distribution of land in Jamaica is extremely unbalanced. According to the last census of agriculture in 1968, a total of 150,000 farms (or 79%) have holdings totalling 224,000 acres of land (or 15%), while the remaining 21% of farms account for 85% of the total 1.5 million acres of agricultural land. A general term "Small Farm" is used to indicate those farms having a holding less than 25 acres. Those farms are mostly situated in the upland regions of the nation's watersheds. The size group, numbers of farm and their acreages are shown below:

1/ Dr. G. Bonnick, Central Planning Unit, oral report to the Agricultural Mission of Taiwan, Republic of China, on March 7, 1970.
Note: The Central Planning Unit is now incorporated into the National Planning Agency.

NUMBER, ACREAGE AND SIZE OF SMALL FARMS IN JAMAICA, 1968

Size Group of Farms (Acres)	Number of Farms	Acreages (Acres)
0	5,099	0
1	52,273	21,640
1 - 5	92,331	202,178
5 - 10	24,741	162,310
10 - 25	12,140	171,238
TOTAL	186,584	557,366

The 1968 survey also shows that the number of farms in the 0 - 5 acres group increased from 70% (1954) to 79% (1968) of the total farms in Jamaica, yet the acreage decreased by some 15,000 acres in that group within the same period.

3.2.4. Agriculture

Agricultural holdings occupy about half of the island and over 33% of the labour force is presently engaged in agriculture and related fields.

Virtually, the agriculture of Jamaica can be divided into two main types. One is plantation type or export-oriented agriculture, and the other is small farmer type or mainly domestic agriculture. The former type deals with larger estates which are situated mostly on the plains, whereas the latter type comprises a vast number of small farms in the steep hilly watersheds. Both types are vital to the nation as a whole. While the export farm products are essential to the country's economy, the production of the import substitutes and the protection of the hills are equally important.

3.3. LAND USE AND CROPS

3.3.1. Land Capability (Appendix 8)

3.3.2. Land Use Statistics

The land use statistics compiled by the Town Planning Department (1971) are from many sources; the major source being the forest inventory of the UNDP/FAO JAM 505 Project - and is set out in the following table.

LAND USE STATISTICS AND CHANGES IN JAMAICA
1961 vs 1970

Unit: 1,000 acres

	1961		1970		Changes
	Acres	%	Acres	%	%
Forest including forest plantations	655	24.1	655	24.1	No
Other Woodland (incl. Scrub Forest)	559	20.6	538	19.8	-0.8
Agriculture (incl. Improved Pasture)	1268	46.7	1258	46.4	-0.3
Natural Range & Grassland	113	4.2	103	3.8	-0.4
Swamp	50	1.8	50	1.8	No
Mining	7	0.3	7	0.3	No
Urban	59	2.2	100	3.7	+1.5
Barren	4	0.1	4	0.1	No
TOTAL	2715	100.0	2715	100.0	

Source: A National Physical Plan for Jamaica

It is apparent from the above table that in the period 1961 - 1970 there were not many changes in the overall picture of land use. The general impression is that a great deal of the lands are idle. According to the Town Planning Department (1971), the acreage of idle land is approximately 225,000 acres. In addition, there are another 525,000 acres of land which are not intensively used, including barren land, swamps, some ruinate, natural woodland and grassland. This leaves about some 750,000 acres to 800,000 acres of land under intensive agricultural use. (Appendix 9)

Out of the total agricultural lands, about 50% or 600,000 acres are situated in rolling and steep uplands, mostly occupied by the small farmers. Many are really subsistence type of farmers with very little education. Their methods of cultivation are often primitive, causing erosion to the steep slopes. Not only the productivity of these lands has been reduced by a quarter to one third (Dumont 1963), but also these lands constitute the most serious problem in Jamaica's watersheds.

3.3.3. Crops

As stated earlier there are some 800,000 acres of land under various crops and comparatively intensive use. Besides large acreages of sugar cane and a few other crops grown on flat plains, the majority of the crops are grown on the slopes of the uplands watersheds. The distribution of those crops in 1970 and their acreages were as follows:

ACREAGE OF MAJOR CROPS 1970

	Total Acreage		On Sloping Land
	1970	%	Acreage 1970
Sugar Cane	167,700	35	58,700
Bananas	84,000	90	75,600
Coconuts	137,500	80	11,000
Citrus	30,000	90	27,000
Coffee	15,000	100	15,000
Cocoa	32,000	100	32,000
Ground Provisions	18,200	100	18,200
Vegetables (Selected)	15,000	80	12,000
Legumes	18,000	80	14,400
Tree Crops (not including forest)	27,800	100	27,800
Other Crops	11,200	50	5,600
Improved Pastures	250,000	80	200,000
TOTAL	806,400		497,300

Source: (1) National Physical Plan for Jamaica (1971)
(2) Report on Domestic Food Crops (1970)
(3) Interviews with Agriculture Commodity Boards

3.4. WATER RESOURCES

3.4.1. Quantity and Distribution

There are no exact figures about an overall water budget in Jamaica. Based on Williams' estimates (1969) and the Town Planning Department (1971), however, the following rough balance sheet has been worked out:

Rainfall	13,500 MGD */	100%	77 inches
Evapo-transpiration	7,500 MGD	55%	42 inches
Streamflow	5,000 MGD	37%	29 inches
Groundwater storage and deep seepage	1,000 MGD	8%	6 inches

With an average rainfall of 77 inches annually, Jamaica has, in theory, sufficient sources of water to satisfy all kinds of uses for the present time as well as for the foreseeable future. In addition to surface water, large areas of the limestone country possess sources of groundwater.

The main problem in Jamaica, therefore, arises from the distribution of water in location and time. Besides the northeast part of the Blue Mountains, the remaining island has a definite dry period ranging from two to six months (Rockie, 1956). In the years 1967 and 1968 and again in 1973 to 1975 droughts hit the island resulting in long periods of water restrictions and agricultural losses. Severe water restriction and cuts were also experienced during these times. Even in normal years, trucking water for domestic use is a common practice in dry seasons for most of our watersheds.

To meet the projected needs of a fast growing population particularly of the Kingston Metropolitan Area, urgent planning and feasibility studies are being undertaken to find alternative sources of water including the possible diversion of water from the Blue Mountains Watersheds to the Kingston area.

*/ Million gallons per day.

3.4.2. Quality and Pollution

Water quality and pollution have been a growing concern among authorities in the fields of domestic water supply, town planning, public health, water resources as well as among land use and watershed protection managers. A water pollution seminar was held in May 1972 to discuss policy, planning and programming of pollution and quality control.

Pollution of the major rivers such as Rio Minho, Rio Cobre, Black River, Great River, as well as Kingston Harbour becomes increasingly serious. Kingston Harbour is seriously polluted by industrial waste, sewerage and oil spills, etc., resulting in half of the bottom waters of the inner harbour being under abiotic condition and the entire harbour being unfit for bathing. [2/]

Heavy silt-laden water alone has caused a lot of trouble and damage to the island. It is not uncommon for many of the island's water treatment plants to be forced to shut down during heavy rainfall periods because of the high turbidity of the streamflow. The muddy water sometimes spread over several miles in the bays and harbours and last for a few days. This is bad for recreation or tourism or for marine life.

There is every reason to believe that the pollution and water quality problem will become more and more acute in the coming years unless overall control measures are practised.

2/ Wade, B. A. 1972. Coastal Water Pollution in Jamaica With Special Reference to Kingston Harbour.

3.4.3. Hydro-Meteorological Stations

Jamaica has at present a total of 108 stream gauging stations [3/] well distributed in the major watersheds. Over half of the stations are less than fifteen years old; the older stations have existed for about 33 years. The whole network (Appendix 10) is the responsibility of the Water Resources Division of the Ministry of Mining and Natural Resources.

Collection of rainfall data in Jamaica dates back more than 100 years. Rainfall stations are well over 500; however, stations with homogenous records longer than 25 years are about 80 (Appendix 10). Some of the rainfall data have been published; a recent publication is an average of monthly and annual rainfall totals, from 369 stations covering the period 1931 - 1960.

3/ These stations are being maintained by the Water Resources Division of the Ministry of Mining and Natural Resources.

CHAPTER 4

PROTECTION OF CULTIVATED SLOPES IN HILLY WATERSHEDS

4.1. GENERAL

Cultivation on steep slopes in humid countries such as Jamaica without protection measures causes serious watershed problems. The results are not only deterioration of the productivity of the land "on site" by water erosion, but also aggravation of the silting and flood damage "off site", i.e. the downstream area. In Jamaica the problems are further compounded by the fact that these cultivators of steep slopes are mostly small farmers. The situation is that whereas resettlement and complete changing of land use is neither feasible or desirable from the socio-economic standpoint, the country's land and water resources are under constant threat by these activities.

However, by applying terracing and protected waterways, these steep slopes can be cultivated safely and profitably. Crop production can be increased, erosion minimized and the farming environment improved.

There are generally four types of bench terraces, i.e. level, outward sloped, conservation bench and reverse sloped (Appendix 11). For this discussion, the reverse sloped type, which is built sloped inversely towards the hill and is particularly suited for steep hilly watersheds is considered.

Soil Conservation Treatments: Their Specification and Applications

Six kinds of treatments, all reverse sloped, are discussed: (a) bench terraces; (b) hillside ditches; (c) individual basins; (d) orchard terraces; (e) mini-convertible terraces; and (f) hexagons. The cross-sectional views of these terraces are shown in Appendix 12. With these six kinds of land treatment, slopes between 7° to 30° can be safely cultivated in the watersheds provided the soils are of sufficient depth. Where the slopes exceed 30° the land should be planted to forest trees. Lands that are too shallow or too wet, but below 25° should be put to pasture.

4.2. GENERAL DESCRIPTION OF TREATMENTS

4.2.1. Bench Terraces

They are essentially a series of level or nearly level strips running across the slope supported by steep risers. The risers are either built by earth protected with grass or by rock walls, if rocks are available. Bench terraces can be built and cultivated by manual labour, animal drawn tools or by machines. The detailed cross-sectional view, terminology and computations of this type of bench terrace are shown in Appendix 13.

4.2.2. Hillside Ditches

The hillside ditch is a discontinuous kind of narrow, reverse-sloped terrace built across the land in order to break long slopes into a number of short slopes so that the runoff will be safely intercepted and drained before causing erosion. The cross-section of this kind of narrow bench is more convenient for maintenance than the conventional type of ditch. They can also be used simultaneously as roads. The distance between two ditches is determined by the degree or percent of the slope. The cultivated strip between two ditches should be supplemented with agronomic conservation measures or auxillary soil conservation treatments.

4.2.3. Individual Basins

Individual basins are small round benches for planting individual plants. They are particularly useful for establishing semi-permanent crops on slopes for controlling erosion, conserving fertilizers and moisture and if mulching is practiced for keeping weeds away. They can be applied to dissected lands with varying depth of soils. They should normally be supplemented by hillside ditches or orchard terraces.

4.2.4. Orchard Terraces

Orchard terraces are narrow bench terraces built on very steep slopes, from 25^{o} to 30^{o}, and their spaces or intervals are determined by the planting distance of the fruit or food trees. Because of steepness, the spaces between should be kept under a permanent grass cover. The trees can be planted either on the terrace or on the individual basins in the grass strips.

4.2.5. Mini-convertible Terraces

Mini-convertible terraces are terraces of medium width built according to the distance used for hillside ditches. Field crops are planted on the terraces whereas fruit or food trees are planted in between. Should the future use of sloping lands in the watershed become more intensive than today, then the spaces between terraces could be converted also into terraces. If the reverse is true, due to labour shortage, then all the terraces could be planted to orchard crops.

4.2.6. Hexagons

A unit hexagon is a special arrangement of farm roads on a slope that envelopes a piece of land which can be made easily accessible to four-wheel mechanization. The enveloped road or branch road goes around the slope to connect with each operation route or terrace which is entered by an obtuse angle. A group of hexagons forms a honeycomb like arrangement with no land wasted. This land treatment is primarily for mechanization of orchards on a large block of land with uniform terrain and can be applied on steep slopes (up to 20^{o}).

4.3. SPECIFICATIONS AND APPLICATIONS OF TREATMENTS

The specifications and applications of the above mentioned six major treatments are summarized in Appendix 14. However, some supplementary notes are given in the following sections.

4.3.1. Width

For bench terraces, the proper width should be determined first by the crops needs, tools to be used, soil depth and slope, as well as farmer's interest. Too wide a bench (flat strip) will not only be too costly, but also needs a deeper cut into the soil profile and results in very high risers which is undesirable. The widths listed for hand made and machine built bench terraces in Appendix 14 show their approximate ranges.

For hillside ditches and orchard terraces, 1.8 m or 6 feet wide is usually sufficient although the latter can be wider when soil is deep and the slope is around 25^{o}. A width of 3.4 m or 11 feet is found as minimum requirement for machine built terraces and for mechanization.

4.3.2. Vertical Intervals and Spacings

(a) Bench Terraces

To find out the vertical interval (VI) is the next important step after determining the width, because it not only gives the approximate height of the riser, but also gives basic data for calculating the the cross-section and the volume of soil in a unit area. It is also used as a guide for staking terraces on the ground.

The vertical interval (VI) is actually the elevation difference between two succeeding terraces. It is determined by the slope of the land and the width of the benches, using the following formula:

$$VI = \frac{S \times Wb}{100 - S \times U}$$

Where VI: vertical interval in feet or metres
S: slope in percent (%)
Wb: Width of bench in feet or metres
U: Slope of riser (ratio of horizontal distance to vertical rise using value 1 for machine built terraces and 0.75 for hand made ones)

(b) Hillside ditches and mini-convertible terraces
This is the same equation as used in other countries for broad base terraces:

$$VI = aS + b$$

Where VI: vertical interval between two ditches in feet
S: slope in percent (%)
a: constant of geographical location
b: constant for soil erodibility and cover condition during critical periods

The value of "a" and "b" varies from region to region and to the soil and cropping conditions. However, 0.3 is used for "a" in humid conditions whereas 2 is used for "b" where auxillary conservation treatment is applied to the spaces between. In Jamaica, a table of spacings of hillside ditches on various slopes has been worked out and has proved very useful (Appendix 15). The same table can be used for mini-convertible terraces.

In countries where the metric system is used, a similar equation is employed as follows:

$$VI = \frac{S + 4}{10} \quad \text{or} \quad VI = \frac{S + 6}{10}$$

Where VI: vertical interval in metres

S: slope in percent (%)

4.3.3. Length

The length of a terrace is limited by the size and shape of the fields, the degree of dissection and the permeability and erodibility of the soil. It should be noted that longer terraces will increase operation efficiency in future cultivation, especially for mechanization. They also reduce cost of construction. However, too great a length in one direction may cause accelerated runoff and erosion. Based on current experience, a maximum of 100 m (330 feet) in one direction is recommended for local conditions.

4.3.4. Grade

It is most important to control the grades of a terrace. In areas of light rainfall and permeable soils, the horizontal grade can be lower than 0.5 percent, whereas in an area of intense rain and heavy soil, one percent is preferable to get rid of the excess runoff. A reverse grade of 5 percent is also required for the bench terraces in order to keep the runoff at the cut area or the toe drain, rather than on the loose fill area which is susceptible to sliding. For narrower terraces, a ten percent reverse grade is needed to take care of water which may collect on the terrace during an intense storm.

4.3.5. Riser and Riser Slope

The height of the riser is dependent on the width of the terrace. Too high a riser is always a risk for protection and maintenance. A height of 1.8 m to 2 m (6 ft. to 6.5 ft.) after settling is found to be a practical limit. Appendix 14 shows the heights of risers in relation to some land slopes and widths of benches.

The slope of a riser depends on the texture of the soil, the tools and materials to be used for building the terraces. For average conditions, the riser slope is 1:1 for machine built terraces and 0.75:1 for hand made terraces provided they are compacted well enough and eventually protected by a dense grass cover or rock wall.

4.3.6. Minimum Soil Depth

The minimum soil depth for the bench terraces can be obtained by dividing the height of the riser by two. For the other discontinuous type of terraces, the depth of cutting is equal to the riser height after settling. All these can be calculated using the equations in Appendix 13. Appendix 16 also gives the minimum soil depths required for some widths of benches on different slopes.

4.3.7. Slope Limit

Hand made terraces can be applied to a slope range of 7^{o} to 25^{o} (12% to 47%) while the machine built ones from 7^{o} to 20^{o} (12% to 36%). For tree crops, 1.8 m (6 feet) discontinuous type of orchard terraces can be employed up to 30° slope if the soil is deep enough. Thirty degrees (30°) is a practical limit for all kinds of terraces. Otherwise, the riser will be too high and wide and the bench will be too narrow resulting in a large percentage of the area being left in riser. This is apart from the natural instability of terraces constructed on very steep slopes.

It is generally not recommended to use bench terracing on slopes gentler than 7° (12%) for two reasons:

(a) simple conservation treatments can be easily adopted up to a 7° slope; and

(b) slopes of 0° - 7° do not usually present obstacles to mechanized farming.

4.3.8. Net Area

The net area, or the area in flat benches after terracing, is very important in the context of land use. This can be calculated by the equation listed in Appendix 13. For a given land slope and riser slope, the net area of the bench terraces will be the same regardless of the bench widths. For instance, on a 13° slope, a hectare or an acre will produce 80% of the flat benches regardless whether the bench width is 11 feet or 15 feet. The steeper the slope, the less net area there will be realized. On 25° slope, the net area of the continuous type of bench terraces is only 63.5% whereas on 7° slope it is 87.8%.

4.3.9. Specification Tables and Volumes

A specification table can be computed step by step according to the equations listed in Appendix 13, for different widths of bench terraces and different slopes for planning and field uses. The volumes of cut and fill can finally be obtained. The same procedure can also be used for other kinds of terraces, except hexagon enveloping roads. Two sample specification tables (Appendices 17 and 18) for machine built bench terraces and one for hand made hillside ditches are given for reference.

4.4. PLANNING, SURVEYING AND STAKING SOIL CONSERVATION TREATMENTS IN WATERSHEDS

4.4.1. Planning

The planning and layout of terraces should include field examinations and consideration of topography, slope, soil, depth, texture, past erosion, the presence of rocks, present vegetation and land use, and future crop plans, etc. If conservation farm plan or land capability maps are available, they will be most helpful.

After carefully examining the above mentioned factors, decisions should be made on the proper kind of terrace for the location, its width and the tools to be used. The vertical interval, the height of riser and the volume of earth to be cut and filled, can be obtained from the Specifications Tables.[1/]

Before starting to stake out the terrace, decisions should be made on the site and type of waterway system and road network. Windbreaks, if necessary, should be also located. All of these should be integrated into terracing work. A sketch map for all the decisions about each particular field should be kept for future reference.

4.4.2. Surveying and Staking

There are two ways of surveying and staking out the terraces depending on the tools to be used for cutting the terraces

[1/] Available from the Ministry of Agriculture - Hope Gardens - Kingston 6.

and the kinds of terraces. For both methods, staking should start from the first terrace at the top of the field. After staking out, corrections should be made if the graded contour lines have sharp bends or very uneven widths between them.

(a) Centre Line Method

This is to survey and stake out the centre lines of the terrace according to the vertical interval. After completing the staking of all centre lines, a line of stake is added in the middle of every two centre lines (cut and fill being equal) by eye judgement to indicate that it is the bottom line of the upper terrace and also the top line of the succeeding lower terrace.

In the case of the discontinuous type of terraces such as hillside ditches and orchard terraces, after centre lines are staked out for distance along the slope, a top line and a bottom line should be set parallel to the centre line at an appropriate distance to indicate the width of the ditch or terrace.

This method is particularly good for all hand made terraces. The centre line should be retained and marked as a guide for the non-cut and non-fill line during the entire period of construction. The area above this line is the cutting area, while the area below is the fill area. This method also enables the surveyor to start staking from the proposed waterway by one percent graded contours to ensure the future runoff will come to a desirable spot as outlet.

(b) Two Line Method

This method does not stake out centre lines. Instead, it is to survey and stake both the upper line and bottom line of a terrace with proper distances to form the planned width of the terrace. A specification table should be consulted to find out the width of the terrace (wt) which is determined by the width of the bench (Wb) planned on the particular slope.

Before staking, an up-and-down guideline (baseline) should first be set on a representative slope of the proposed area. Then stakes are set along this line at distances equal to the terrace width (wt), or the width of road and grass strip in the case of hexagons. After this is done, graded contour lines can be staked out from each of the guide stakes. This method is suited to a uniform slope of a large block of land where machines will be employed for cutting terraces.

4.5. CONSTRUCTION OF TERRACES

Regardless of what kind of tools are to be employed for terracing, the cut and fill should be gradually done and depth equal so that no extra soil needs to be disposed of or taken from another place.

(a) Construction by Manual Labour

Generally speaking, a man cuts and fills 5 cu. yards of earth during eight hours of work. This may vary with the width of the terrace, type of soil, and the presence of tree roots or rocks. If the following rules are observed, the work efficiency and quality can be ensured:

I. Build the terrace when the land is not too dry or too wet.

II. Start building the terrace from the top of a hill and proceed downslope. In case of heavy rain it will not be washed away. When the top soil treatment is practised, it is necessary to build from the bottom up. Temporary protection measures should then be practised.

III. The initial cut should be made right below the top stakes. Fill work should be started against the bottom stakes. By doing so, it will eventually reach a desirable grade without over-cutting. Sometimes, rocks can be placed along the bottom lines, or turn the sods along the bottom stake lines before fill.

IV. After every six inches of fill, the soil should be compacted firmly by a beater. When the fill is too thick, it can hardly be compacted. Terraces going across existing depression areas should be built particularly strong.

V. The edge of a terrace should be built a little higher than planned because of settling. The rate of settling may be as high as ten percent of the depth of fill.

VI. Both the reverse and horizontal grades should be checked constantly with a level during construction. Corrections should be readily made wherever necessary.

VII. Shape the slope of the riser to 0.75:1.

VIII. Waterway shaping should be commenced only after the terraces are cut. Be sure all the terrace outlets are higher than the waterway floor.

IX. A team of three men for narrower terraces and four for wider terraces will be a good unit for efficient terracing work.

(b) Construction by Machine

A medium sized machine such as the Caterpillar D-6 bulldozer with angled blade can be employed for cutting wider terraces below 15^{o} slope. A smaller one may be used for cutting narrow terraces on even 20^{o} slopes. So far as efficiency and economy are concerned, the D-6 can do a far better job if the slope is not too steep. The average production per hour for a fairly efficient D-6 bulldozer is as follows:

Width of Bench (Wb) Feet	Production per hour cubic yards
11	58.8
15	56.9
19	54.9
23	53.3
27	51.9

The following are some of the rules to be observed:

I. Start cutting parallel to and about 1.5 feet from the top line of the stakes and push the dirt down slope and dump it just above the bottom line. The best efficiency will be maintained when the bulldozer travels down slope about three times its length or approximately 40 to 45 feet for dumping.

II. When it cuts parallel along the top line, attention should be paid to the full load of the bulldozer blade. As soon as the blade is full, not earlier and not much later, the bulldozer should be headed down to the dumping area.

III. After dumping about one foot tick along the bottom line, the dirt should be compacted by the bulldozer. Whenever the bulldozer needs to travel from one end of the terrace to another, it should always run on the edge of the bench for compacting.

IV. Each time use the angled blade for cutting about sixteen to twenty inches. Continue cut and fill until the desirable grades, reverse and horizontal, are attained. Mark the elevations of fill at the lower line of stakes with coloured ribbons as check points.

V. Do not cut or fill at the proposed waterway site, and avoid overcutting at the toe drain.

VI. Close supervision is necessary. A dumpy level should be used for checking the grades during construction. Final grading or smoothing should be done as soon as the level checking is made.

VII. Shape the riser slope to 1:1.

(c) Top Soil Treatment

Bench terraces usually expose the infertile subsoil which could result in lower production unless some prevention or improvement measures are undertaken. One of these methods is top soil treatment. Where fertile top soil exists, top soil treatment is always worth undertaking. There are two ways of doing it:

I. The terraces can be built from down slope up. After the bottom terrace is partially cut, the top soil from the slope above is then pushed down to the bench and spread on it. The next to the bottom terrace, in the same fashion, gets its top soil from the area above. This proceeds uphill until the top one is built without top soil. For a medium sized bulldozer, it needs about eight extra hours to treat one gross acre in this manner.

II. The second method is to push the top soil away to either ends before cutting the terrace and pushing it back when cutting is completed. For hand made terraces, the top soil can be piled along the centre line or at certain intervals, provided that the bench is wide enough.

4.6. WATERWAYS AND ROAD REQUIREMENTS

4.6.1. Waterways

The waterway is an integral part of terracing in the humid regions. In most cases, a natural depression without shaping and protection is not safe enough to accommodate extra runoff concentrated by terracing. On average, an area of two to two and a half acres requires about 300 feet of waterway. For larger blocks of land, the same waterway could serve up to five acres. On an acre basis 150 - 200 feet of waterway may be enough.

(a) Waterway Planning

The site and kind of waterway(s) for a special field depend on the slope, velocity and amount of runnoff, and tools to be used for cultivation. It is always desirable to find a gentle depression area for the site of waterway plus shaping and revegetation. When the velocity of runoff exceeds six feet per second, engineering structures are usually needed for additional protection. A grassed waterway alone is seldom safe to be applied on steep slopes, i.e. more than 11^{o} or 20% slope. In the steep hill region, waterway structures cannot be avoided.

The waterway is usually sited at one end of the field. Sometimes, however, two waterways instead of one are needed, one each at both ends of the terraces to handle large quantities of runoff and when the terraces are longer than 330 feet. Sometimes, a waterway can be installed in the middle of the terrace leaving the two ends for access roads. A stepped waterway should be built in the middle if four-wheel cultivation is required. The same waterway can be used as a pathway for going up and down the terraces. On gentle slopes, a waterway can be combined with road ditches for tractor crossing.

(b) Types of Waterways and Structures

There are many types of waterways depending on the material available, shape of the channel, purposes and structure needs. A waterway can also have many different sections according to the protection needs. The following are brief descriptions of some major types of waterways. Their uses and approximate limits are shown in Appendix 19.

I. Grassed Waterway: This is a parabolically shaped channel planted with low and rhizome types grass. The channel should be shaped with a uniform cross-section and as consistent in gradient as possible. It is the most inexpensive type of waterway on gentle slopes and its maintenance is easy. Using this waterway as a pathway should be always avoided.

II. Grassed Waterway with Drop Structures: On moderately steep slopes or in discontinuous types of channel, small drop structures and check dams can be used in combination with grass to take care of the steep sections. The structures should not be taller than six feet and the gradient between the apron of the upper structure and the weir of the structure immediately below should not be over three percent to ensure their stability.

III. Ballasted Waterway: Suitable on moderately steep slopes where large quantities of head-sizes stones are available. Ballasting the parabolic channel with stones keyed in the ground can provide a good protection. On steeper slopes or for large quantities of runoff, wire mesh should be used to help in keeping the stones in place.

IV. Prefabricated Concrete Waterway: On very steep slopes and where it rains frequently so that normal construction is hampered, prefabricated structures, parabolic or V-notch type, can be used to protect the centre part of the waterway leaving the two sides protected by grass. They can also be used in these channels where there are constant small flows due to seepage or ground water.

V. Stepped Waterway: This is a series of drop structures with basins and are used to protect the steep risers of the terraces whereas on flat benches, parabolic grassed waterways of three percent are used to connect the drop structures. The grassed portion of benches can easily be crossed by a tractor and the structures on steep risers can be used for collecting the silt and also as pathways. It is usually built in the middle of terraced fields.

VI. Waterway and Road Ditch Complex: To combine road ditch and waterway as one channel on gentle slope is not only economic, but also convenient for four-wheel mechanization. In such a case, the road should be built reverse-sloped allowing road water to drain to the channel and also the terraces should be sloped toward the same channel. The channel should be shaped parabolically and protected with ballasting of stones for tractor passing.

VII. Foot-path and Chute Complex: On very steep slopes where mechanization is not applicable, a rectangular or trapezoid type of concrete or masonry chute can be built with steps in the middle for both draining runoff and for use as a pathway. It is particularly practical for small farmers.

(c) Waterway Installation

I. Shaping: All types of waterways should be shaped as uniformly as possible in cross-section and gradient. Sharp turns and sudden falls should be avoided, unless where a water collecting basin is planned or drop structure is to be built. Structures should be installed on solid cut soils or solid rocks wherever possible. Stakes, strings or bamboo arches to indicate the shaping area and depths are practical devices needed. It is also important to shape the waterway lower than the terrace outlets to ensure water flowing in.

II. Grass Planting: An ideal grass for lining the waterway is one that is available locally and is the rhizome type or sod-forming type. Seeding is cheaper than sodding, but it should be done in shallow furrows and with mulching at the beginning of the rainy season. Strip-sodding can provide quick protection. Sometimes pegs are used to stabilize the sods. Hydro-seeding techniques can also be employed.

III. Construction of Structures: The following are some important principles regarding the construction of structures.

- The water must go over the structures, and not go around them.
- This is perhaps the most common cause of structure failure. For drop structures, side walls must be high enough to direct the flow to the weir of the structure and cut-off walls behind, beside and below the structure to prevent water from seeping through are needed.

For any type of chute, cut-off walls are always necessary.

- Structures must be built on cut and solid soil and the foundations should be deep and strong enough. Steel bars or wire mesh are needed for chutes and for taller drop structures built with cement blocks.
- The apron or stilling basin of the drop or chute should be built strong enough to dissipate the energy of the falling water and prevent undermining.
- Enough good quality mortar should be used to ensure that the structure will be watertight and not permit water to flow through causing leakages.
- After the structure is built, tramp earth solidly behind or around it to prevent cracking.
- Provide sodding at the junction of the earth and the structure to avoid water tunnelling.

4.6.2. <u>Roads are also essential to any terracing programme for Mechanization</u>

(a) Road access to and from terraced areas is required for four-wheel mechanization. On gentler slopes, the roads could be built up-and-down hills. On steeper slopes, they should be built diagonally across the field. The maximum grade for this kind of tractor road is 7^{o} to 8^{o} (12% to 14%). Because bench terraces can be used as roads, there is no need of roads transversing the slope. Generally speaking, 250 feet of road per acre should be ample for even rugged and dissected terrains. The appropriate width is about eleven feet.

There are four types of road systems which can be used to cope with the different field conditions and mechanization requirements. They are as follows:

I. Two road system: Two up-and-down roads to connect both ends of the terraces at approximately right angles to the terraces. They are ideal for mechanization on gentle slopes (below 10° or 18%). On large blocks of land, each road could serve two sides.

II. One road system plus U-turn: On moderately steep slopes or where there is no room for system I, this type could be employed. A road is built to connect one side of terraces whereas at the other side, a U-type short road is connecting every two terraces for the tractor to turn around.

III. One road system: If the benches (flat strips) are wide enough for tractor turning, one road connecting one end of each terrace should be sufficient. Or, the road could go through the terrace field diagonally in the case of steeper slopes and round hills.

IV. Hexagon system: It has been explained previously. This system is particularly suited to big farms and full mechanization of orchard crops.

(b) For Manual or Animal Cultivation

The road requirement for manual or animal cultivation is less rigid. A width of about six feet should be ample and the road gradient can be up to 15° (26.8%) or more. One acre needs about 150 feet of roads.

4.7. PROTECTION AND MAINTENANCE

Protection measures on newly built terraces, waterways and roads and their maintenance are essential to the success of the overall terracing programme. Field work and farmers should carefully examine the terraced area during the first two rainy seasons. Any damage should be immediately repaired before it becomes worse. Many terracing programmes have failed, not because of design or construction, but to negligence in protection and maintenance.

4.7.1. Protection Measures:

(a) For Terraces

- After the risers are properly shaped, grasses should be planted or hydro-seeded on the risers. Local grasses of rhizome type are much more desirable than tall grasses, although the latter may produce forage for cattle.
- The terrace outlets which are always critical should be well protected either by sod-forming grasses of by small checks (using a piece of rock or brick to form a check).
- On that part of the bench where the stepped waterway is crossing, grasses should also be established.
- Auxillary conservation treatments or grasses should be well established between the discontinuous type of terraces.

(b) For Waterways

- In most cases, grasses are planted to protect the channel or part of the channel. In rainy season, mechanical support is sometimes needed, such as using pegs to anchor sods or mulching for seeding.
- Waterways should be protected from other use, such as paths or for transporting materials.

(c) For Roads

- Unstable road banks should be protected by various methods, e.g. wattling and staking, sodding or hydro-seeding.
- Steep road surfaces should be protected either by grasses, marl or stones. In any case, cross drains are needed. The distance between two drains can be decided by the following formula, which is a modification of the one used by the U.S. Forest Service and proved to be very successful in Jamaica:

$$I = \frac{800}{S}$$

Where I: Interval along the road surface by foot

S: Slope in percent (%)

Steep road ditches should be protected by ballasting or a combination of grass and small loose rock checks.

4.7.2. Maintenance

A total of twelve mandays a year for maintaining one acre of bench terraces should be ample. For hillside ditches and orchard terraces, etc., it should be much less.

(a) For Terraces

For Benches:

I. Keep the toe drains always open and properly graded and do not permit any accumulation of water in any part of the terraces.

II. Allow for runoff to collect at the toe drains for safe disposal to the protected waterway. Obstacles like continuous mounds or beds should be broken to permit water passing to the toe drains.

III. Keep grasses and weeds from the benches.

IV. Maintain proper reverse slopes of the benches or basins and reshape them immediately after crops are reaped. Ploughing should be done carefully so as not to destroy the toe drains and the reverse grade.

(b) For Risers:

I. Do not allow any runoff flow over the risers.

II. Keep grasses growing well on the risers. Weeds and vines which threaten the survival of the grasses should be cut back or uprooted. Grasses should be kept low and fertilized.

III. Any small break or fall from the riser should be repaired immediately.

IV. Keep cattle away to avoid trampling on risers or eating the grass.

(c) For Outlets:

I. Check the outlets and see whether they are adequately protected.

II. Any silt in the outlets should be cleaned.

(d) For Soil Productivity:

I. Deep ploughing, ripping or sub-soiling is needed on the cut part of the bench terraces to improve the structure of the soils.

II. Green manuring, composting or sludge application is also needed in the initial period for improving soil fertility.

III. Maintain soil productivity by proper crop rotation and fertilizing.

(e) For Waterways

I. Keep the water flowing through the waterways, instead of going around or underneath the structure. Any detectable breaks should be repaired immediately.

II. Brush or large weeds should be removed before they weaken the grass. The whole waterway should be kept in dense and low grass cover and as uniform as possible to avoid a turbulent flow.

III. Structures should be checked at least twice a year, once before the rainy season and the second, after the rains. Any minor cracks, tunnels and breaks around or on the structure should be repaired before they are too big or become very serious.

IV. Clean out silt trapped in the stilling basins. The silt can be put back on the terraces.

V. Keep stones properly fastened at ballasted waterways.

(f) For Roads

I. Maintain a proper profile of the cross drains and clean silt out of the drains after heavy rains.

II. Prevent use of the roads by heavy trucks when they are too wet or soft.

III. Culverts and side ditches should always be kept open.

IV. Re-shape road surface if there appears to be track erosion either by wheels or by hooves of animals.

4.8. COSTS AND BENEFITS

4.8.1. Costs

(a) Costs of Terracing

The cost of terracing per unit area depends on slope, soil, type of terraces, width of bench, presence of rocks or tree stumps, and tools to be employed for cutting them. If the width is fixed, the steeper the slope, the more expensive the terracing work will be. If the slope is fixed, however, the wider the bench, the more costly it will be, although the percentage of bench or flat area in a unit area is still the same. If volumes to be cut are the same, machine built terraces are generally cheaper than hand made ones. But, the type of road and waterway required for mechanization may affect the total cost greatly. Discontinuous type of terraces, i.e. hillside ditches, orchard terraces, etc., generally cost much less than bench terraces.

Costs of waterways and roads vary from one field to another. Generally, terraces for mechanization should cost more because of waterway structures and road construction. Costs like riser stabilization, soil improvement (optional cost) and terrace maintenance, etc., can also be estimated to the actual inputs. Roads and waterway costs can be estimated from the labour and material required for them.

Appendix 20 sets out the costs of different soil conservation at the present time. An annual cost per acre for bench terraces of from US$70 to US$80 with or without soil improvement should be a fair estimation. For discontinuous types of narrow terraces, the annual cost can be much lower, because the cutting and maintenance cost less.

Small farmers can use their own labour to complete the terracing of their own farms over four to five years, with technical service and incentives such as subsidies from the Government. It would not overburden the farmer, if the terracing cost which is mostly family labour and materials, can be spread out over a number of years and he can do the work in the slack periods.

(b) Benefits

Terraces and other soil conservation treatments in the watershed can be expected to increase farm production by an average of twenty to thirty percent. They conserve fertilizers, moisture and top soils, and gradually build up soil fertility. They also facilitate better cultivation and management practices. In many instances, the production per unit area has more than doubled. The UNDP/FAO Forestry Development and Watershed Management Project at its Smithfield Demonstration area in Jamaica has tripled the production of both Lucea Yam and Yellow Yam (Dioscorea spp.) in newly terraced areas. The net return per acre of yam, after deducting the annual cost of terraces, is around JA$1,200.

(c) Protection from Erosion

Runoff and soil loss plot studies in many tropical countries have shown that various types of terracing will cut down a considerable amount of soil loss in comparison with the traditional way of cultivation on the slopes.

For example, the results of a four year soil loss experiment on 17^{o} slope in Yellow Yams in the northwest of Jamaica, where the annual rainfall is 130 inches, showed that an average of dry soil loss per acre per year from the check plot was 54 tons, while from the bench terrace plot it was 7 tons. Hillside ditches with continuous mounds or with individual hills yielded 11 tons and 16 tons respectively. In terms of soil depth, the check plot lost 0.43 inches a year, while the bench terraces lost 0.06 inches.

(d) Other Benefits

In addition to the above, terracing programmes have many other benefits as follows:

- Minimize sedimentation and stream pollution
- Reduce runoff and flood damage
- Intensify land use
- Create arable lands and enable free choice of crops
- Stimulate improved farming practices
- Improve drainage and provide better sites for cultivation
- Facilitate mechanization on steep slopes
- Maximize irrigation benefits
- Encourage permanent farming and reduce shifting cultivation and forest fire
- Promote labour intensive programmes and create new job opportunities
- Beautify landscapes and provide better environment

A terracing programme will, in the long run, serve to protect and enhance the land and water resources of Jamaica for posterity and for sustained production. It is similar to public health programme or national defence, which are all necessary to a nation. A cost-effectiveness analysis of such a programme may be more meaningful than the usual cost/benefit analysis and its difficulty to attach a dollar value on some benefits which accrue.

With the current worldwide food shortages, scarce foreign exchange, a deteriorating environment, it is very pertinent that we in Jamaica use our unemployed labour force to protect, rehabilitate and improve our hilly watersheds at the same time making them more productive.

CONCLUSION

A major problem associated with most of the land used for agriculture in Jamaica's watershed is the unfavourable topography.

Personnel concerned with agricultural development and watershed management have recognized this and the need for watershed protection measures since the 1930's. However, the lack of trained manpower and related resources to undertake effective work on a sufficiently large scale has been the major obstacle impeeding sufficient progress in this direction.

Many simple and less expensive and less permanent watershed management practices in the past have been inadequately designed and implemented resulting in uneconomic and ineffective programmes of watershed management devoid of lasting benefits.

Despite ongoing and planned concentrated development of watersheds, a national programme of watershed management and soil conservation to serve all the watersheds particularly those inhabited by small farmers, is vital. However, such a national programme can only proceed as fast as the trained personnel are available.

In order to treat the watersheds needing protective works within the next thirty years, an average annual target of approximately 13,000 acres is necessary and will require the recruitment and training of more persons at all levels.

To protect the nation's limited land resources, particularly in the upland watershed areas, a close coordination among the Soil Conservation Service of the Ministry of Agriculture, the Forestry Department, and the Natural Resources Conservation Department is recommended with the division of duties as follows:

- The Soil Conservation Service of the Ministry of Agriculture being responsible for Integrated Development works on agricultural lands in the watersheds.

- The Forestry Department being responsible for afforestation.

- The Natural Resources Conservation Department being responsible for:

  (a) Quick protection works, e.g. gully control works and control of landslides;
  (b) Upstream River Training works;
  (c) Revegetation of bare slopes; and
  (d) Protection of small municipal watersheds.

BIBLIOGRAPHY

Champion, H. C. Report on Soil Erosion in the Mahogany Vale Catchment and its Control with Special Reference to Sedimentation in the Future Reservoir. 1966.

Groucher and Swabey. Soil Erosion and Soil Conservation in Jamaica. 1937.

Powell, W. I. Hillside Agriculture in Demonstration Watersheds in Jamaica. UNDP/FAO JAM 505 Project Technical Report 11, Kingston, Jamaica. 1974.

Sheng, T. C. Some Watershed Management Problems of Taiwan and Jamaica. Paper presented at "Seminar on Development and Use of Jamaica's Water Resources" September 13 - 15, 1968.

Sheng, T. C. Watershed Management and Soil Conservation Activities in Jamaica: An Evaluation Report. UNDP/FAO JAM 505 Project Technical Report 9, Kingston, Jamaica. 1973.

Sheng, T. C. Watershed Management - A Report prepared for the Government of Jamaica by FAO based on the work of T. C. Sheng - UNDP/FAO JAM 505 Project Technical Report 12. 1975.

Sheng, T. C. and Stennett, H. R. Lecture Notes, Watershed Management and Soil Conservation Training Course. UNDP/FAO JAM 505 Project Working Document. 1975.

Soil Conservation Unit. Annual Report for Period 1977 - 1978. 1978.

Stalling, J. A. Soil Conservation. Prentice Hall Inc. Englewood Ciffs N. J. 1965.

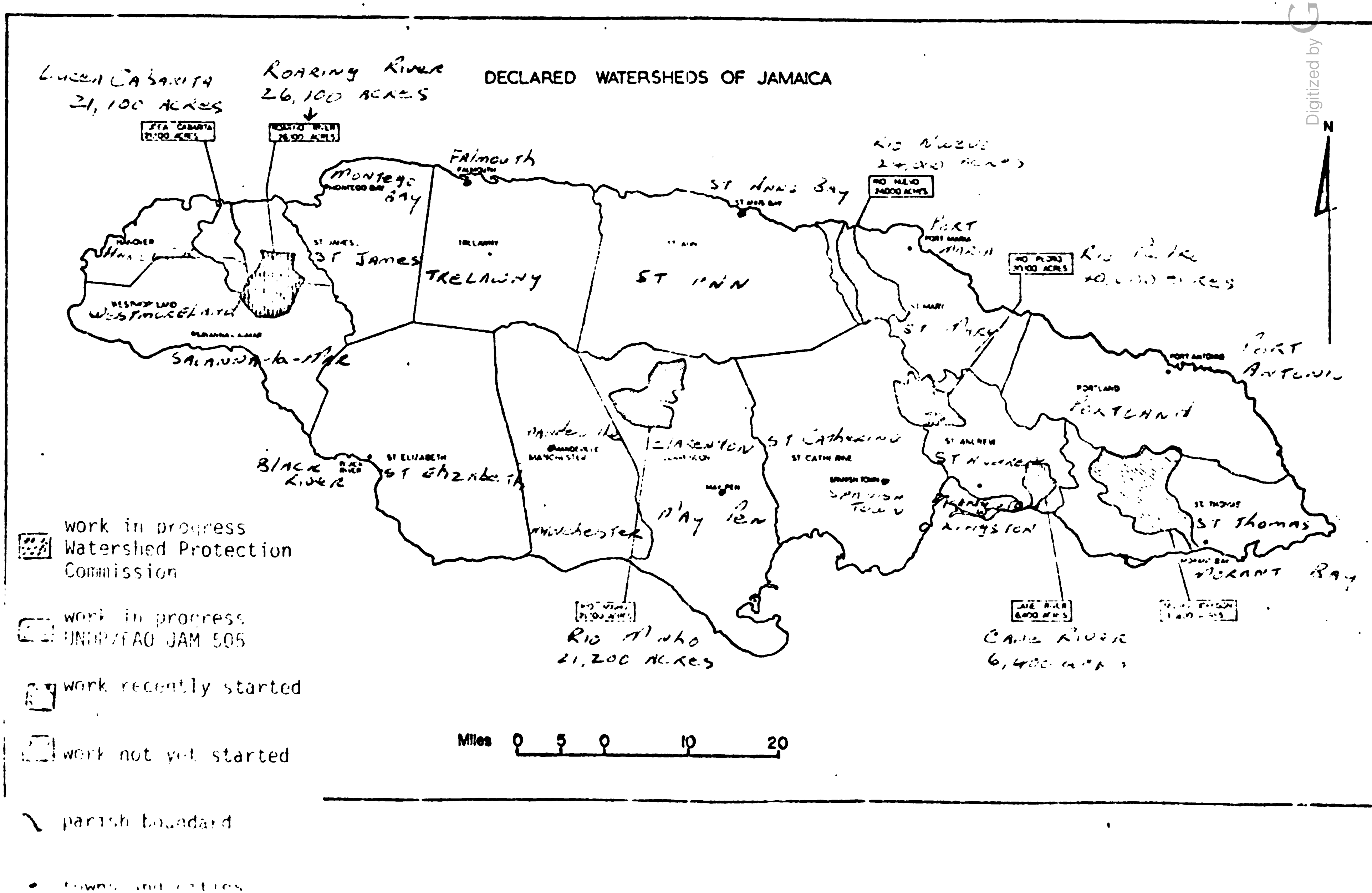
Stennett, H. R. Notes on Soil Conservation Activities in Jamaica. Paper prepared for discussion with Norwegian Mission - unpublished.

Town Planning Department. National Physical Plan Atlas. 1971.

Williams, J. B. Water Resources of Jamaica, a review in Bulletin of the Scientific Research Council Vol. 9 Nos. 1 - 4, Kingston, Jamaica.

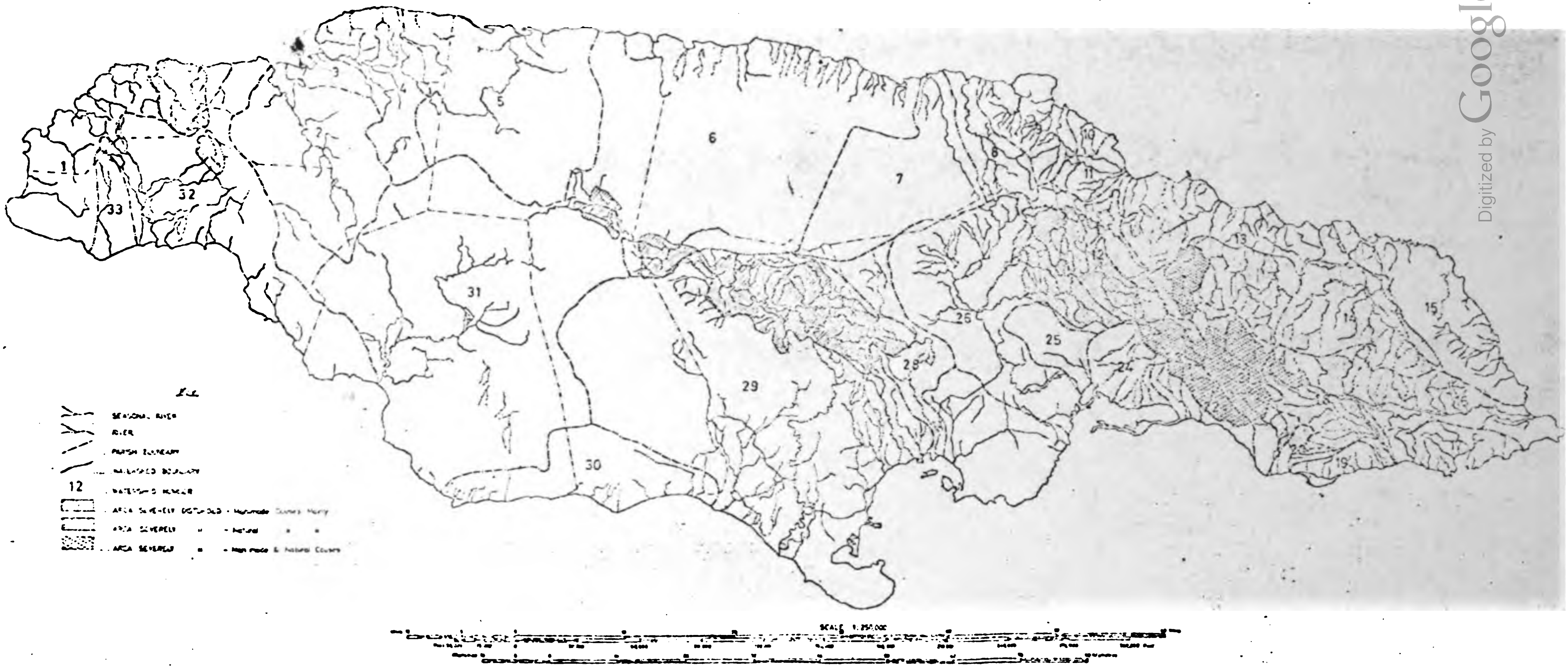
Selection of Critical Watersheds in Jamaica. Working Document. 1973. Unpublished.

WATERSHEDS OF JAMAICA


DECLARED WATERSHEDS OF JAMAICA
Lucea Cabarita 21,100 acres
Roaring River 26,100 acres
Falmouth
Montego Bay
St James
Trelawny
St Ann
St Anns Bay
Port Maria
St Mary
Port Antonio
Portland
St Andrew
St Catherine
Spanish Town
Kingston
St Thomas
Morant Bay
Clarendon
May Pen
Manchester
St Elizabeth
Black River
Westmoreland
Savanna-la-Mar
Rio Minho 21,200 acres
Cane River 6,400 acres
Miles 0 5 0 10 20
N
work in progress Watershed Protection Commission
work in progress UNDP/FAO JAM 505
work recently started
work not yet started
parish boundard

APPENDIX 3

WATERSHEDS REQUIRING PRIORITY TREATMENT



APPENDIX 4

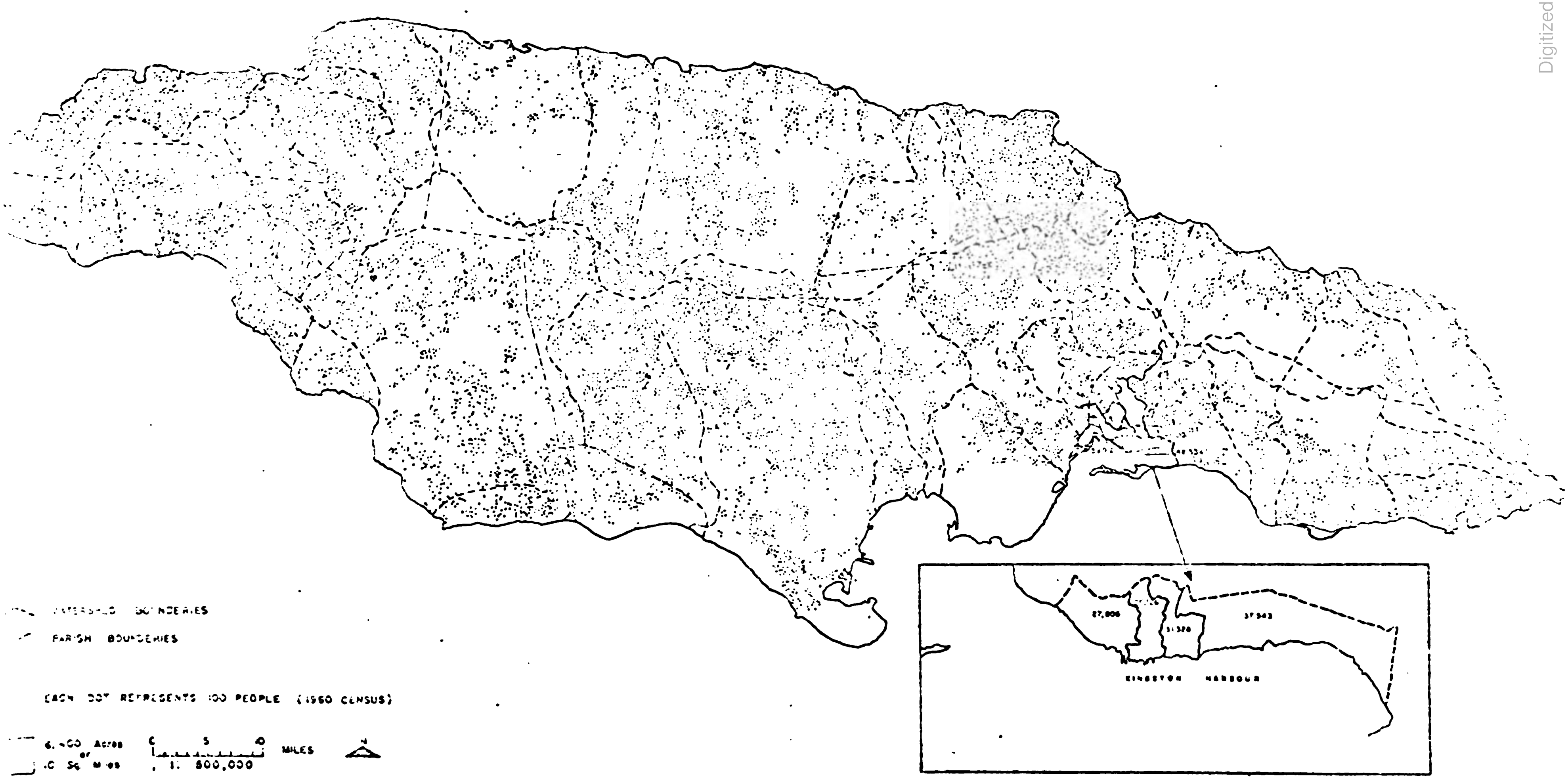
WATERSHEDS SHOWING GEOLOGY

Source.- National Atlas Of Jamaica 1971

APPENDIX 5

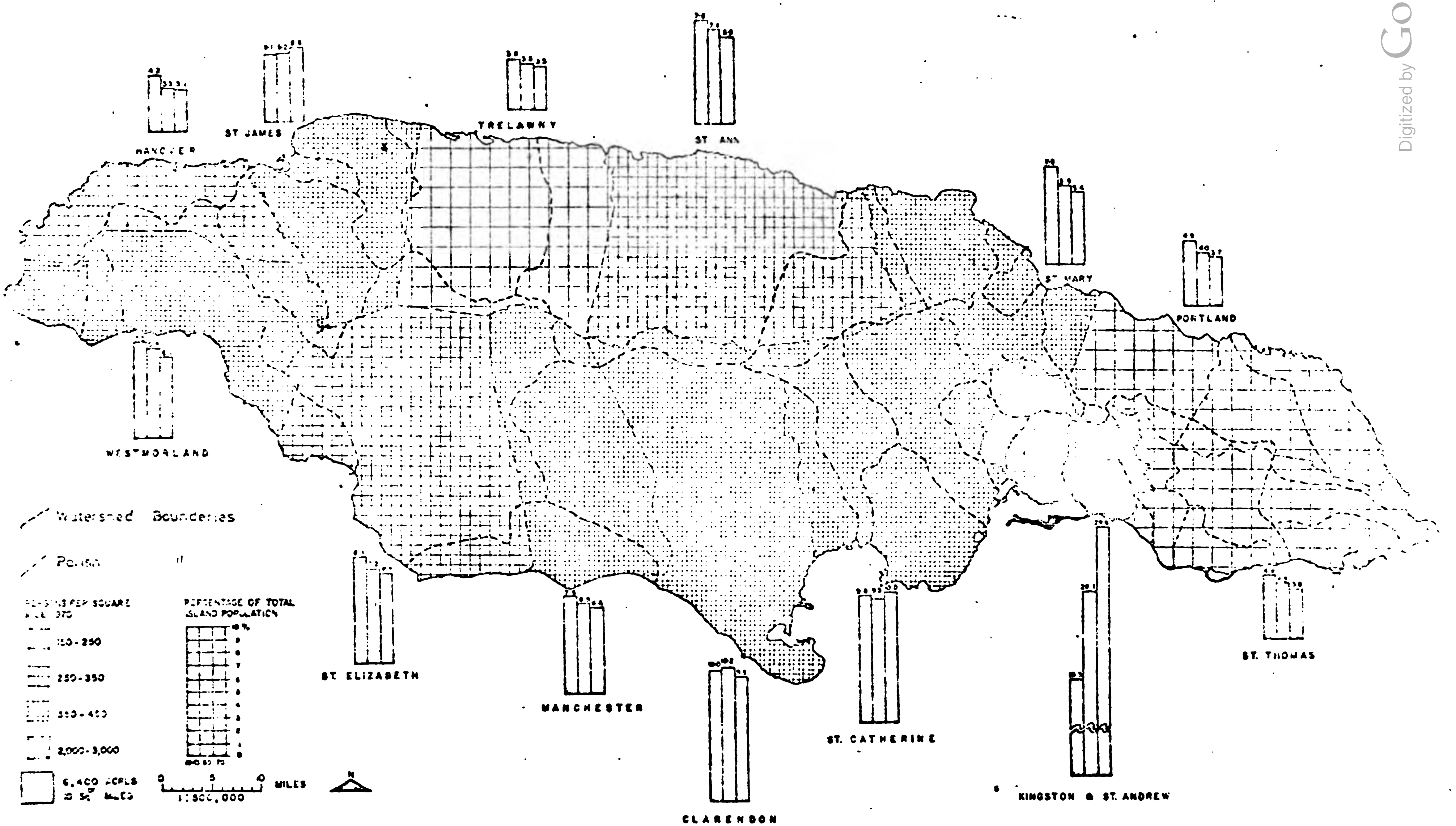
WATERSHEDS SHOWING ANNUAL RAINFALL

WATERSHEDS SHOWING POPULATION DISTRIBUTION



Source:- Atlas Of Jamaica 1971

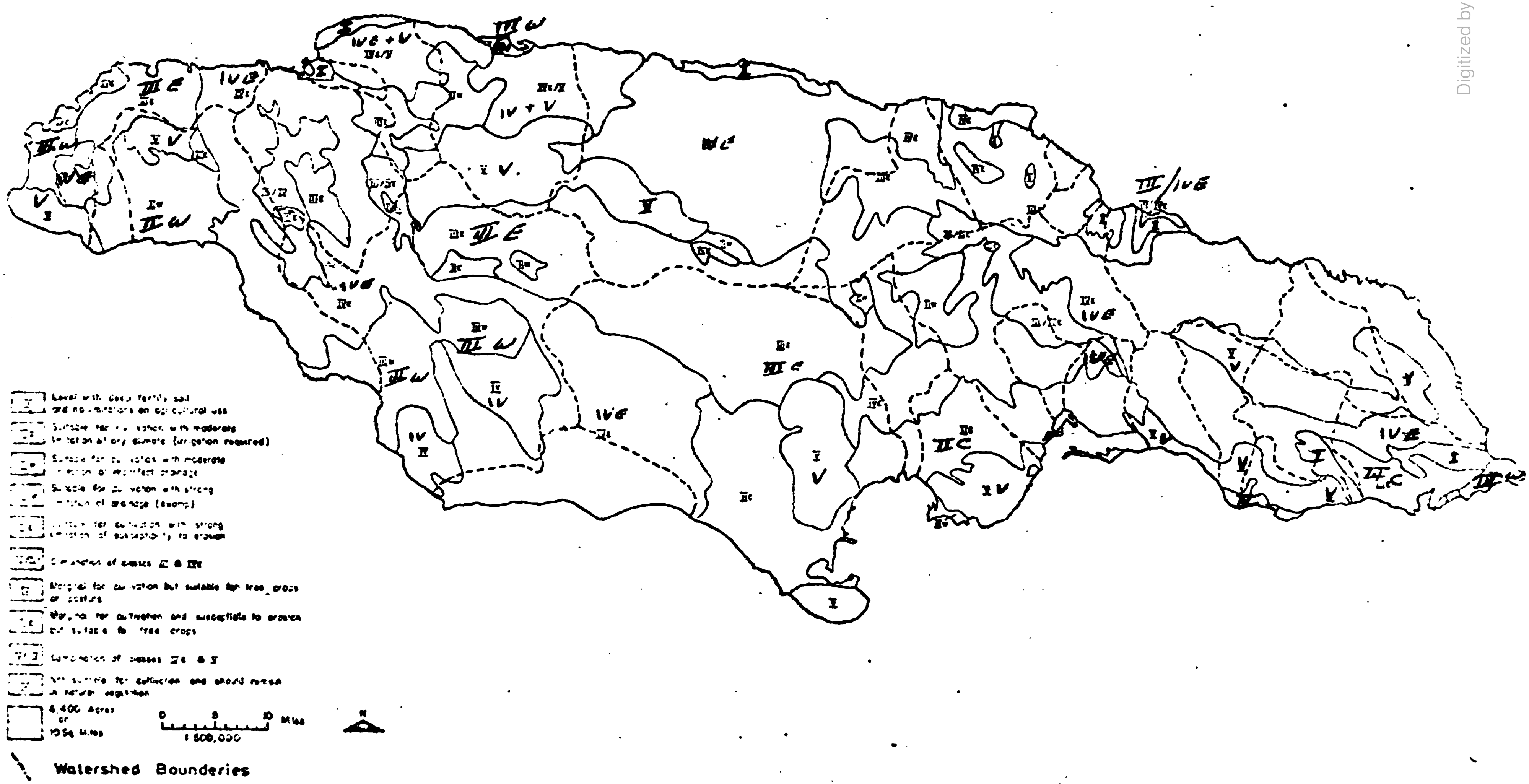
WATERSHEDS SHOWING POPULATION DENSITIES



Source:- National Atlas Of Jamaica 19

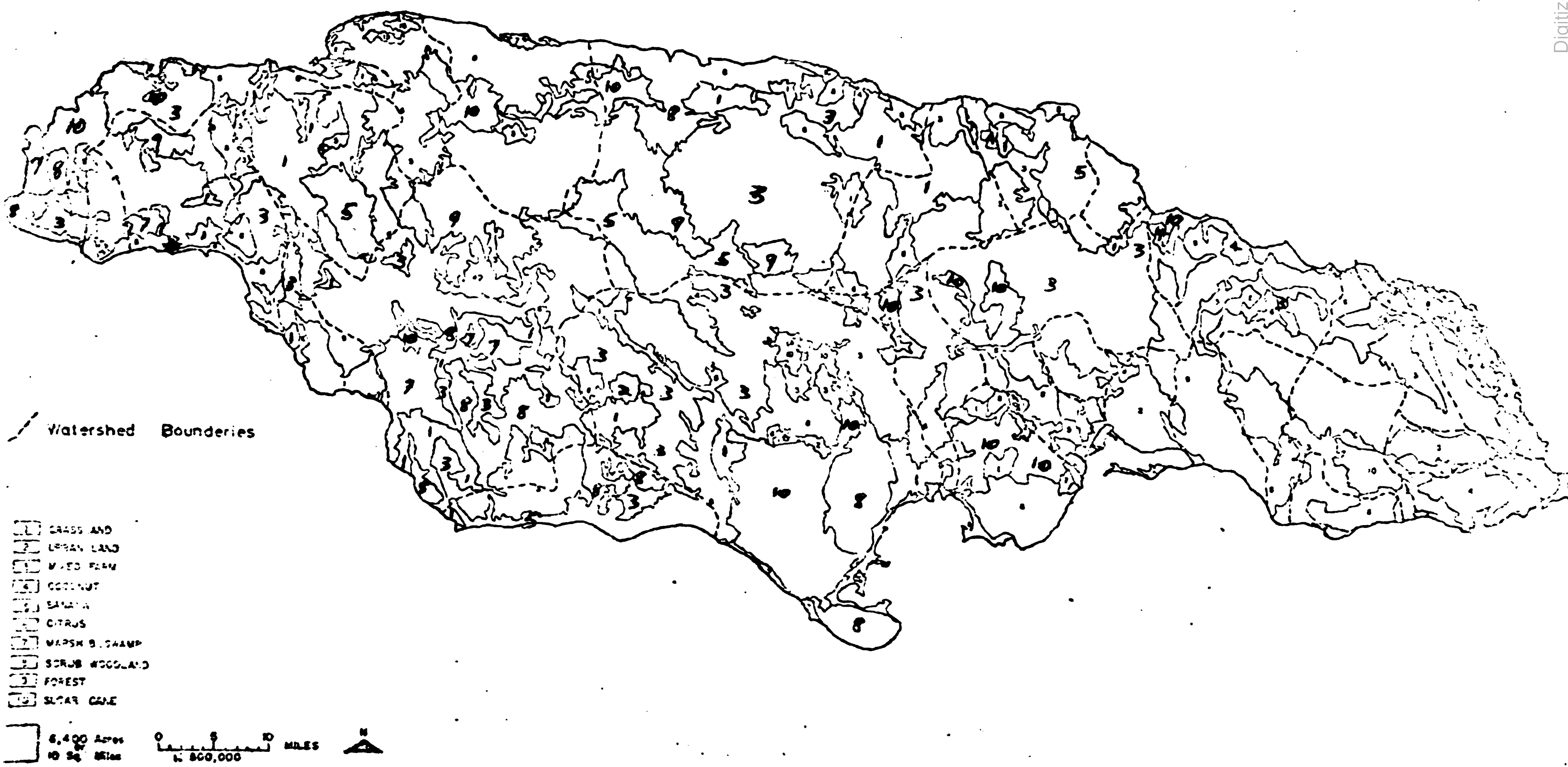
APPENDIX 8

WATERSHEDS SHOWING AGRICULTURAL LAND CAPABILITY



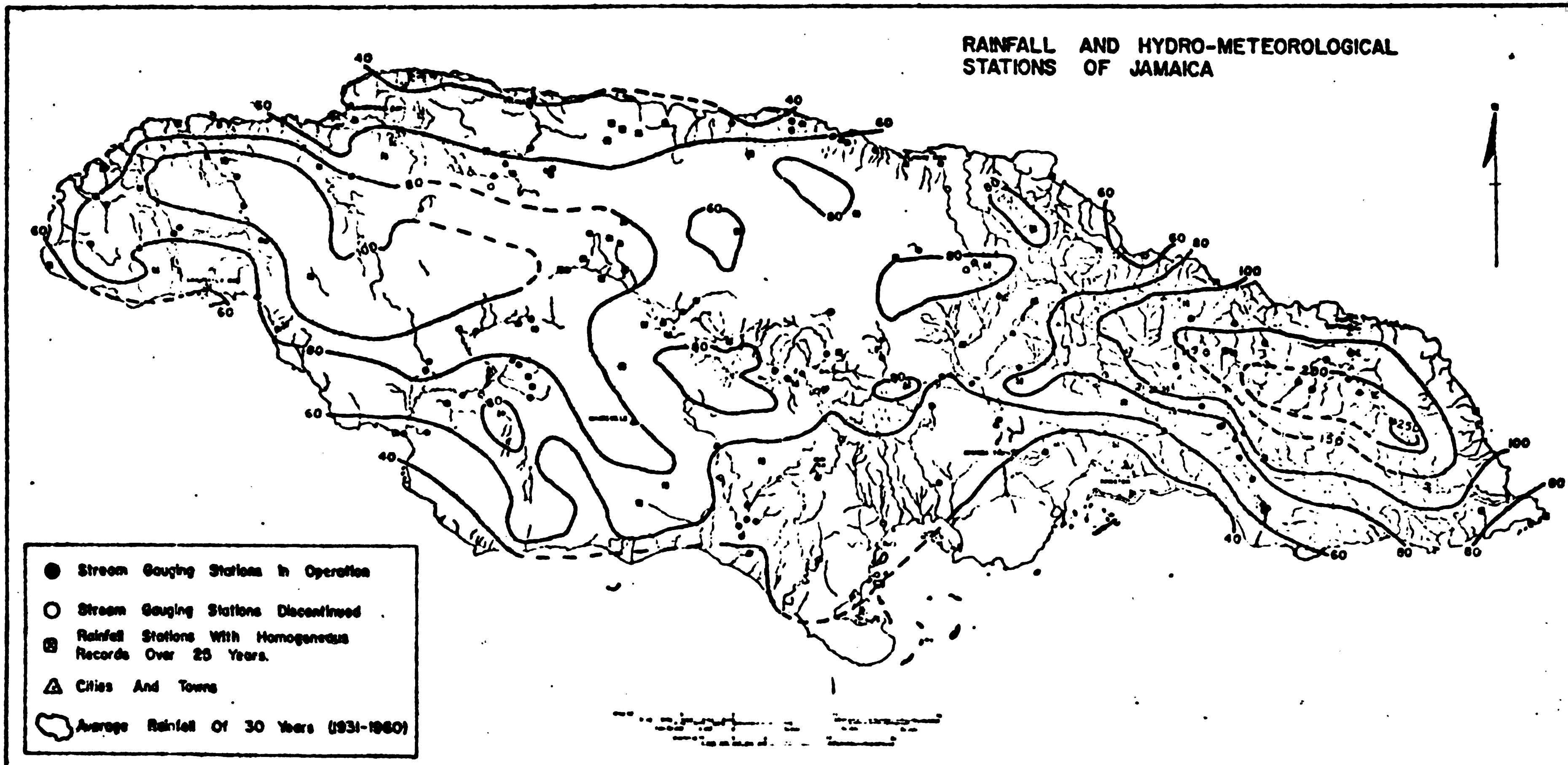
Source:- National Atlas Of Jamaica 197[illegible]

WATERSHEDS SHOWING LAND USE



Source:- National Atlas Of Jamaica 1971

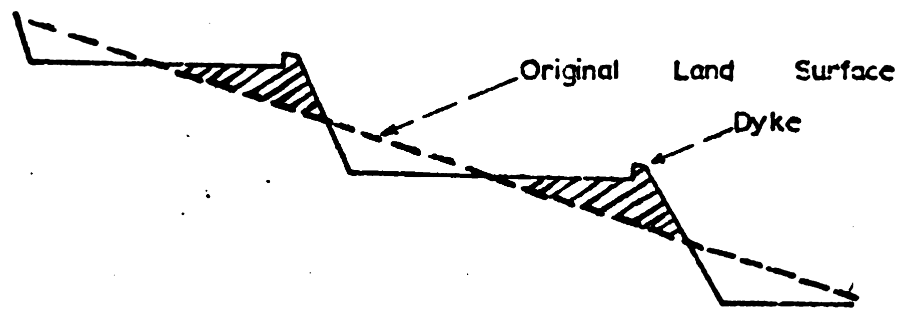
APPENDIX 10


RAINFALL AND HYDRO-METEOROLOGICAL STATIONS OF JAMAICA
Stream Gauging Stations In Operation
Stream Gauging Stations Discontinued
Rainfall Stations With Homogeneous Records Over 25 Years.
Cities And Towns
Average Rainfall Of 30 Years (1931-1960)

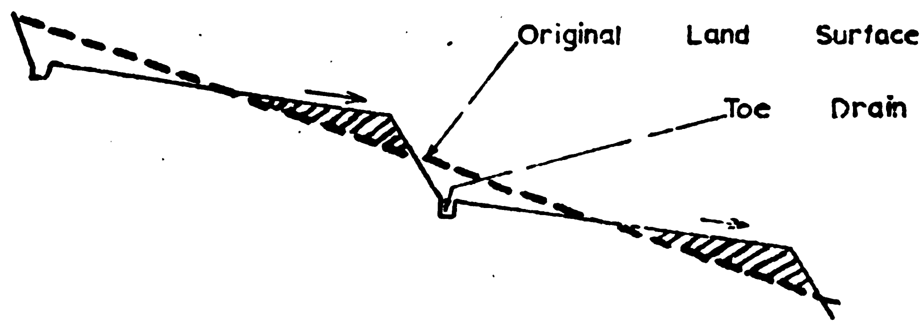
APPENDIX 11

TYPES OF BENCH TERRACES

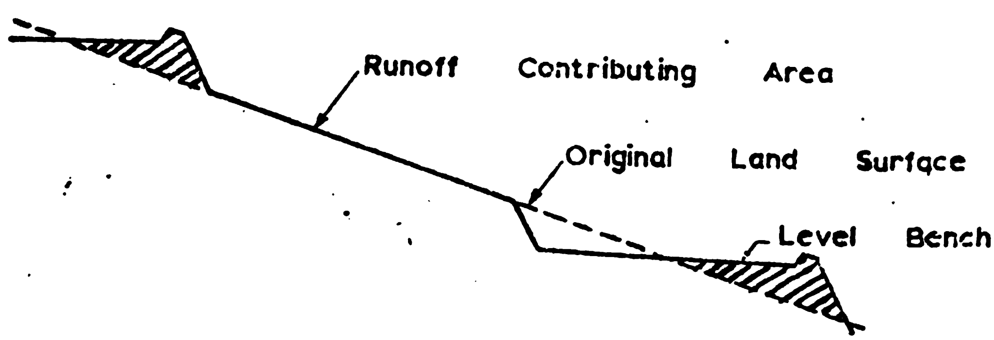
1. LEVEL BENCH TERRACES



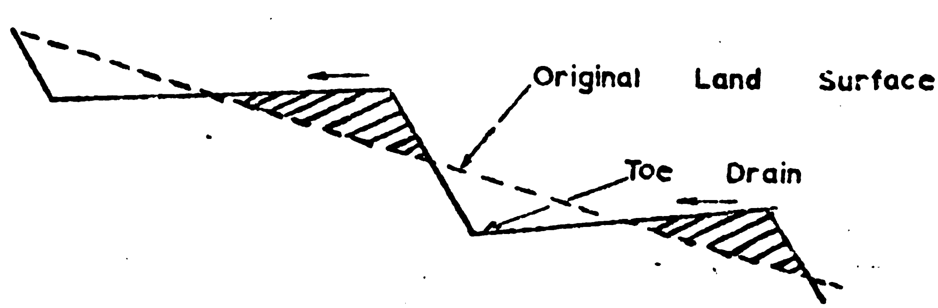
2. OUTWARD SLOPED TERRACES



3. CONSERVATION BENCH TERRACES



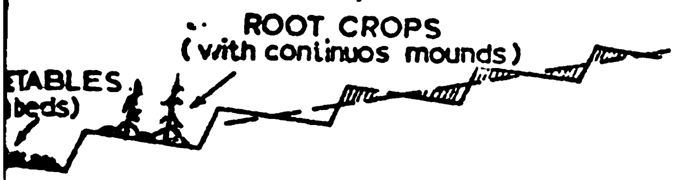
4. REVERSE SLOPED TERRACES



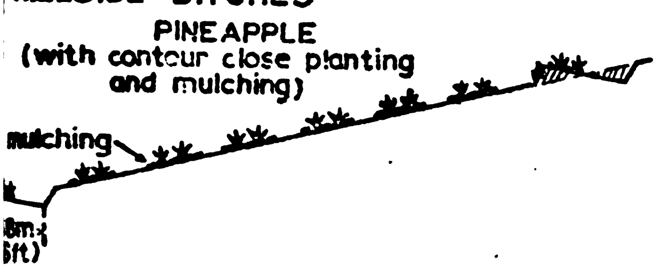
APPENDIX 12

CROSS SECTIONAL VIEWS OF SIX MAJOR LAND TREATMENTS

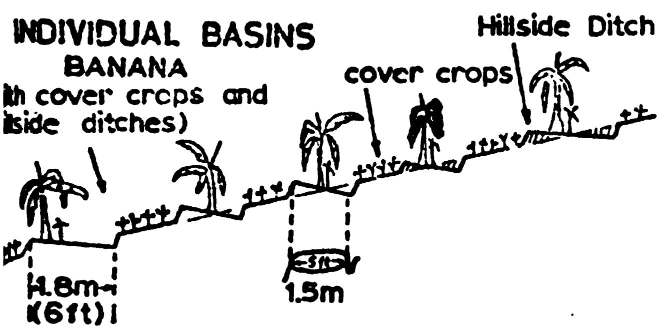
BENCH TERRACES



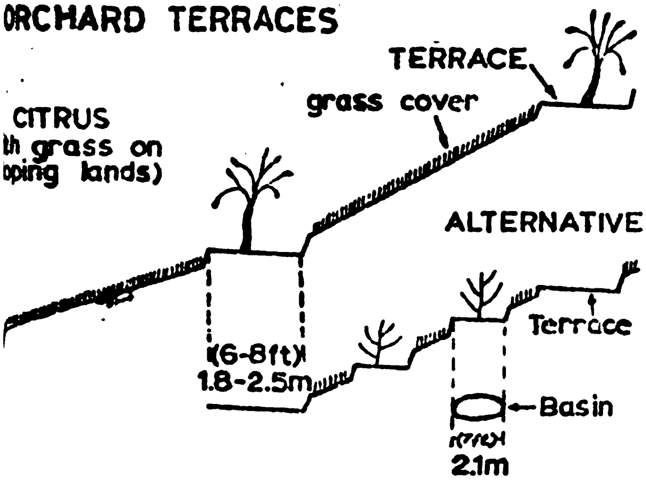
HILLSIDE DITCHES



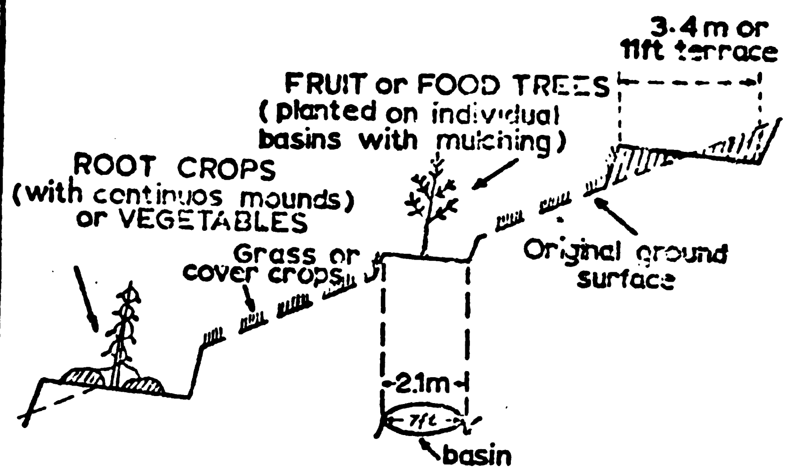
INDIVIDUAL BASINS



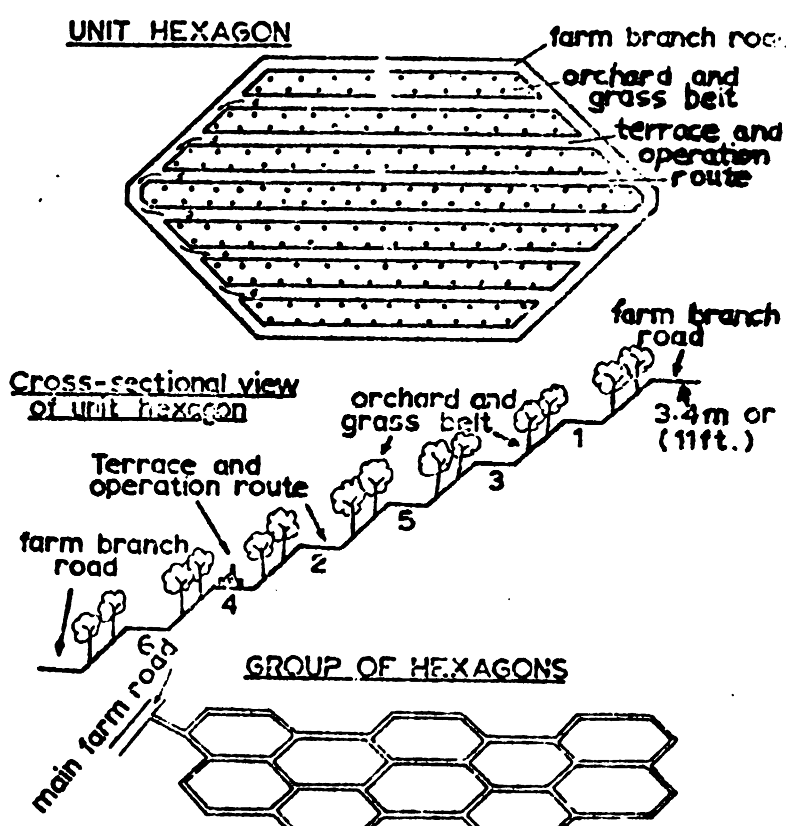
ORCHARD TERRACES



5. MINI-CONVERTIBLE TERRACES

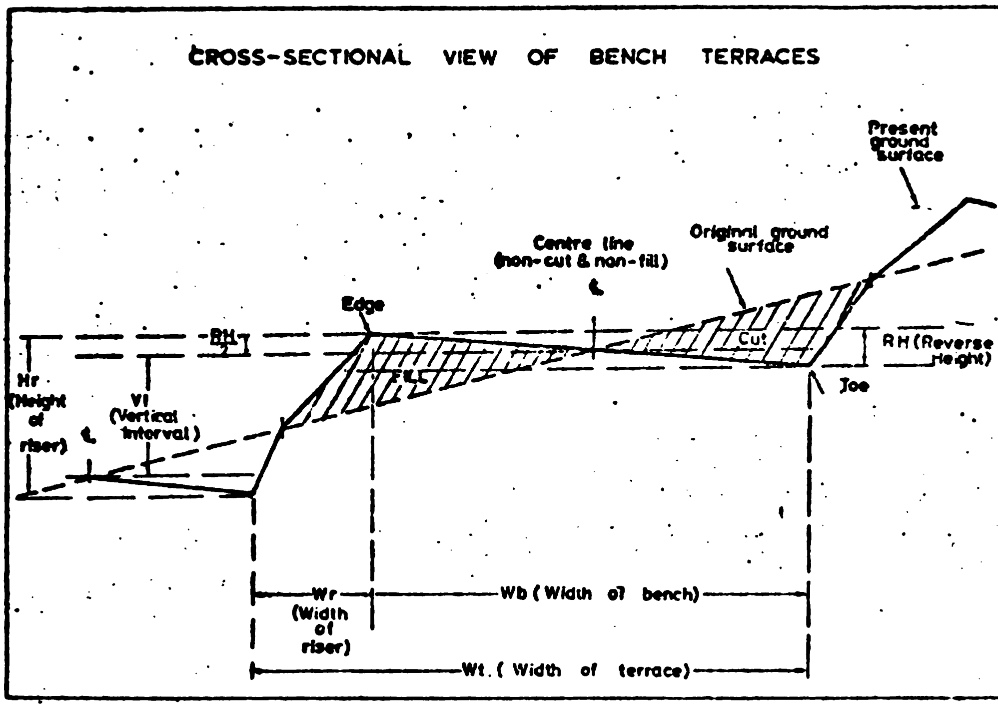


6. HEXAGONS



APPENDIX 13

CROSS-SECTIONAL VIEW AND COMPUTATIONS OF BENCH TERRACE



1. Vertical Interval (VI) : $VI = \frac{S \times Wb}{100 - S \times U}$ (S : Slope in %. U : 1 or 0.75)
2. Reverse Height (RH) : $RH = Wb \times 0.05$
3. Height of Riser (Hr) : $Hr = VI + RH$ (Depth of cut = $\frac{Hr}{2}$)
4. Width of Riser (Wr) : $Wr = Hr \times U$
5. Width of Terrace (Wt) : $Wt = Wr + Wb$
6. Linear Length (L) : $L = \frac{43,560}{Wt}$ (per acre)

   $L = \frac{10,000}{Wt}$ (per ha.)
7. Net Area of Benches (A) : $A = L \times Wb$
8. Percent of Benches (Pb) : $Pb(\%) = \frac{A}{43,560} \times 100$ (per acre)

   $Pb(\%) = \frac{A}{10,000} \times 100$ (per ha.)
9. Cross Section of Terrace (C) : $C = \frac{Wb \times Hr}{8}$
10. Volume to be cut and filled (V) : $V = L \times C$

SPECIFICATIONS AND APPLICATIONS OF SIX KINDS OF TERRACES

Kind	Specifications						Applications	
	Width of Bench (Flat Part)	Length	Horizontal Grade	Reverse Grade	Riser Slope	Land slope	V.I. 1/ or Spacing	Auxilliary Treatments 2/
1. Bench Terraces a. Hand made	(8'–17')	(330')	1%	5%	0.75:1	7^o–25^o (12–47%)	$\frac{S \times Wb}{100-S \times .75}$	–
b. Machine built	(11'–27')	(330')	1%	5%	1:1	7^o–20^o (12–36%)	$\frac{S \times Wb}{100 - S \times 1}$	–
2. Hillside ditches	(6')	(330')	1%	10%	0.75:1	25^o (36%)	a S + b	Contour planting Close planting Mulching Cover cropping
3. Individual basins	(5'–7')	(5'–7')	–	10%	0.75:1	25^o (36%)	Planting distance of crops	Hillside ditches Orchard terraces Mulching Cover cropping Contour planting
4. Orchard terraces	(6'–8')	(330')	1%	5–10%	0.75:1	25^o–30^o (36–58%)	(+20') along slope	Grass cover Individual basins
5. Mini-convertible terraces	(11')	(330')	1%	5%	1:1	7^o–20^o (12–36%)	a S + b	Grass cover Individual basins Mulching
6. Haxagons a. Terraces and operation routes	(11')	(330')	1%	5%	1:1	7^o–20^o (12–36%)	(+20') along slope	Grass cover Individual basins
b. Enveloped or bench road	(11')		7^o (12%)	5%	1:1	7^o–20^o (12–36%)	–	Grass or marling Cross drains

1/ V.I. is vertical interval between two succeeding terraces that determines space.

2/ To be applied mostly in between the terraces or on basin surfaces.

APPENDIX 15

SPACING OF HILLSIDE DITCHES ON VARIOUS SLOPES

Slope		Vertical Interval		Spacing or Inclined Distance	
Degree (o)	Per cent (%)	(ft)	(m)	(ft)	(m)
1	1.8	2.54	0.77	145	44.2
2	3.5	3.05	0.93	87	26.5
3	5.2	3.56	1.08	68	20.7
4	7.0	4.10	1.25	58	17.7
5	8.6	4.58	1.40	52	15.8
6	10.5	5.15	1.57	49	14.9
7	12.3	5.69	1.73	46	14.0
8	14.1	6.23	1.90	44	13.4
9	15.8	6.74	2.05	43	13.1
10	17.6	7.28	2.22	41	12.4
11	19.4	7.82	2.38	40	12.2
12	21.3	8.39	2.56	40	12.2
13	23.1	8.93	2.72	39	11.9
14	24.9	9.47	2.88	39	11.9
15	26.8	10.04	3.06	38	11.6
16	28.7	10.61	3.23	38	11.6
17	30.6	11.18	3.41	38	11.6
18	32.5	11.75	3.58	38	11.6
19	34.4	12.32	3.76	38	11.6
20	36.4	12.92	3.94	37	11.3
21	38.4	13.52	4.12	37	11.3
22	40.4	14.12	4.30	37	11.3
23	42.4	14.72	4.49	37	11.3
24	44.5	15.35	4.67	37	11.3
25	46.6	15.98	4.87	37	11.3

Remarks:

1. Spacing may be decreased as much as 25 per cent and increased as much as 10 per cent to allow for soil, climatic, crop needs and farming practices.

2. From 1 to 6 degrees, the spacings are the same as for the broadbase terraces.

(APPENDIX 16)

RISER HEIGHTS AND MINIMUM SOIL DEPTH REQUIRED IN RELATION TO SOME LAND SLOPES AND BENCH WIDTHS

Width of Bench (Wb)	Slope	Riser Height	Minimum Soil Depth	Remarks
Bench Terraces				
(8 ft)	18° (32.5%)	(3.84')	(23 in)	Hand made
	25° (46.6%	(6.13')	(36.6in)	Hand made
(11 ft)	11° (19.4%	(3.05)	(18.3in)	Hand made
	20° (36.4%)	(6.05')	(36.3in)	Hand made
(15 ft)	14° (24.9%)	(5.72')	(34.3in)	Machine built
(19 ft)	12° (21.3%)	(6.09')	(36.3in)	Machine built
(23 ft)	10° (17.6%)	(6.06')	(36.3in)	Machine built
Hillside Ditches				
(6ft)	11° (19.4%)	(0.98')	(11.8in)	Hand made
	18° (32.5%)	(1.59')	(19.1in)	Hand made
	25° (46.6%	(2.45')	(29.4in)	Hand made
Orchard Terraces				
(6 ft)	29° (55.4%)	(3.14')	(37.6in)	Hand made
(8 ft)	25° (46.6%	(3.06')	(36.6in)	Hand made
Mini-Convertible & Haxagons				
(11 ft)	11° (19.4%)	(1.60%)	(19.2in)	Machine built
	18° (32.5%)	(2.92')	(35.1 in)	Machine built

* This is the limit of the riser height

APPENDIX 17

Sample sheet of specification tables.

Specifications of Machine-Built Bench Terraces

Reverse Slope 5%
Riser slope 1:1

Width of Bench (ft)	Symbols	Unit	13° 23.1%	14° 24.9%	15° 26.8%	16° 28.7%	17° 30.6%	18° 32.5%
13	VI	ft	3.91	4.31	4.76	5.23	5.73	6.26
	RH	ft	0.65	0.65	0.65	0.65	0.65	0.65
	Hr	ft	4.56	4.96	5.41	5.88	6.38	6.91
	Wr	ft	4.56	4.96	5.41	5.88	6.38	6.91
	Wt	ft	17.56	17.96	18.41	18.88	19.38	19.91
	L	ft	2,480.64	2,425.39	2,366.11	2,307.20	2,247.68	2,187.85
	A	ft^2	32,248.32	31,530.07	30,759.43	29,993.60	29,219.84	28,442.05
	Pb	%	74.00	72.40	70.60	68.90	67.10	65.30
	C	ft^2	7.41	8.06	8.79	9.56	10.37	11.23
	V	ft^3	18,381.54	19,548.64	20,798.11	22,056.83	23,308.44	24,569.76
	CY	Yd^3	680.80	724.10	770.40	816.98	863.30	910.00
14	VI	ft	4.21	4.64	5.13	5.64	6.17	6.74
	RH	ft	0.70	0.70	0.70	0.70	0.70	0.70
	Hr	ft	4.91	5.34	5.83	6.34	6.87	7.44
	Wr	ft	4.91	5.34	5.83	6.34	6.87	7.44
	Wt=	ft	18.91	19.34	19.83	20.34	20.87	21.44
	L	ft	2,303.54	2,252.33	2,196.67	2,141.59	2,087.21	2,031.72
	A	ft^2	32,249.56	31,532.62	30,753.38	29,982.26	29,220.94	28,444.08
	Pb	%	74.00	72.40	70.60	68.80	67.10	65.30
	C	ft^2	8.59	9.35	10.20	11.10	12.02	13.02
	V	ft^3	19,787.41	21,059.29	22,406.03	23,771.65	25,088.26	26,452.39
	CY	Yd^3	732.90	780.00	829.90	880.50	929.30	979.80
15	VI	ft	4.51	4.97	5.49	6.04	6.61	7.22
	RH	ft	0.75	0.75	0.75	0.75	0.75	0.75
	Hr	ft	5.26	5.72	6.24	6.79	7.36	7.97
	Wr	ft	5.26	5.72	6.24	6.79	7.36	7.97
	Wt	ft	20.26	20.72	21.24	21.79	22.36	22.97
	L	ft	2,150.05	2,102.32	2,050.85	1,999.08	1,948.12	1,896.39
	A	ft^2	32,250.75	31,534.80	30,762.75	29,986.20	29,221.80	28,445.86
	Pb	%	74.00	72.40	70.60	68.80	67.10	65.30
	C	ft^2	9.86	10.73	11.70	12.73	13.80	14.94
	V	ft^3	21,199.49	22,557.89	23,994.95	25,448.29	26,884.06	28,332.07
	CY	Yd^3	785.20	835.50	888.80	942.60	995.80	1,049.40

APPENDIX 18

Sample sheet of specification tables.

Specifications of Hillside Ditches

Width: 6ft.
Reverse Slope: 10%
Riser Slope: 0.75:1

Slope	Symbols	Units	Specifications
14° (24.9%)	VIt	ft	1.84
	RH	ft	0.60
	Hr	ft	1.22
	Wr	ft	0.91
	Wt	ft	6.91
	L	ft	1,144.00
	A	ft^2	6,864.00
	Pb	%	15.76
	C	ft^2	1.83
	V	ft^3	2,093.52
	CY	Yd^3	77.54
	D	ft	39.00
15° (26.8%)	VIt	ft	2.01
	RH	ft	0.60
	Hr	ft	1.31
	Wr	ft	0.98
	Wt	ft	6.98
	L	ft	1,173.12
	A	ft^2	7,038.72
	Pb	%	16.16
	C	ft^2	1.96
	V	ft^3	2,299.32
	CY	Yd^3	85.16
	D	ft	38.00
16° (28.7%)	VIt	ft	2.19
	RH	ft	0.60
	Hr	ft	1.39
	Wr	ft	1.05
	Wt	ft	7.05
	L	ft	1,185.60
	A	ft^2	7,113.60
	Pb	%	16.33
	C	ft^2	2.10
	V	ft^3	2,489.76
	CY	Yd^3	92.21
	D	ft	38.00

Slope	Symbols	Units	Specifications
17° (30.6%)	VIt	ft	2.38
	RH	ft	0.60
	Hr	ft	1.49
	Wr	ft	1.12
	Wt	ft	7.12
	L	ft	1,185.60
	A	ft^2	7,113.60
	Pb	%	16.33
	C	ft^2	2.24
	V	ft^3	2,655.74
	CY	Yd^3	98.36
	D	ft	38.00
18° (32.5%)	VIt	ft	2.58
	RH	ft	0.60
	Hr	ft	1.59
	Wr	ft	1.19
	Wt	ft	7.19
	L	ft	1,198.08
	A	ft^2	7,188.48
	Pb	%	16.50
	C	ft^2	2.39
	V	ft^3	2,863.41
	CY	Yd^3	106.05
	D	ft	38.00
19° (34.4%)	VIt	ft	2.78
	RH	ft	0.60
	Hr	ft	1.69
	Wr	ft	1.27
	Wt	ft	7.27
	L	ft	1,198.08
	A	ft^2	7,188.48
	Pb	%	16.50
	C	ft^2	2.54
	V	ft^3	3,043.12
	CY	Yd^3	112.71
	D	ft	38.00

APPENDIX 19

MAJOR TYPES OF WATERWAYS: THEIR USES AND LIMITS 1/

Type	Shape	Channel Protection	Velocity Limit	Slope	Uses
Grassed Waterway	Parabolic	By grass	(6ft/sec)	11° (20%)	For new waterway or uniform sloped depression
Grassed waterway with drop structures	Parabolic	By grass and concrete or masonry structures	(6ft/sec)	Between two structures: 3%, overall slope 11° (20%)	For discontinuous type of channel
Ballasted waterway	Parabolic	By stones or by stones and wire mesh	(10ft/sec)	15° (26%)	Where stones are available
Prefabricated concrete waterway					A stilling basin is usually needed at the end
a. Parabolic waterway	Parabolic	By concrete structures and grass	-	20° (36%)	Where rainfalls are frequent and flows are constant
b. V-notch chute	90° V-notch	By concrete structures and grass	-	20° (36%)	Same as above and on very steep slopes
Stepped waterway	Parabolic and rectangular	By grass and concrete or masonry drops	On grass part: (6ft/sec)	Overall slope 20° (36%)	For 4-wheel mechanization and in the middle of bench terraces
Waterway and read ditch complex	Parabolic	By grass and stone ballasting	(10ft/sec)	8° (14%)	For tractor crossing and 4-wheel mechanization
Foot-path and chute complex	Trapezoid or rectangular	By concrete or masonry structure	-	20° (36%)	For paths on small farms and on very steep slopes

1/ These limits are approximations for general reference. In practice, the volume and velocity of runoff and site conditions should all be taken into consideration for determining the type of waterway needed. Most of these types of waterways handle a few acres of runoff.

APPENDIX 20

ADJUSTED SAMPLE COSTS OF LAND TREATMENTS PER ACRE SMITHFIELD DEMONSTRATION CENTRE

Treatment	Description	Man-day or Machine hour	Cost 1969/70	Present Cost June 1978
			J$	J$
Bench Terracing	15 ft wide on 15° slope cutting and final grading cost by D-6 bulldozer	19 hrs	171.0	361.00
Bench Terracing (Hand - made)	9 ft wide on 24° slope, cutting cost and riser protection	190 m/d	380.0	1,387.00
Top soil treatment	Using D-6 bulldozer	10 hrs	90.0	190.00
Hillside Ditching (Hand-made)	6 ft wide on 26° slope, spacing 20 ft (without basins)	32 m/d	64.0	233.60
Orchard Terracing	6 ft wide on 26° slope, spacing 20 ft (without basins)	77 m/d	144.0	562.10
Individual basins (Hand-made)	600 basins of 5 ft diameter, 15° slope, not including hillside ditches	40 m/d	80.0	292.00
Hexagons (Machine)	9° slope, 11 ft wide	16 hrs.	144.0	304.00
Mini-convertible Terracing (Hand-made)	11 ft wide on 18° slope (with basins)	80 m/d	160.0	584.00
Stepped waterway	For 4-wheel mechanization on 15 ft wide terrace	-	130.0	350.00
Prefabricated waterway	For small tractor or hand cultivation	-	80.0	200.00
Grassed waterway	On 9° slope, 6ft wide	16 m/d	32.0	116.80
Farm road	On 15° slope, 11 ft wide, 300 ft per acre, with cross drains	-	72.0	200.00

Remarks
1) 1969/70 average rate for one man-day J$2.0, for one Machine hour J$9.0.
2) Present machine rate is J$19.00 per hour from D-6 Bulldozer.
3) Government wage is J$7.30 per man-day in June 1978.