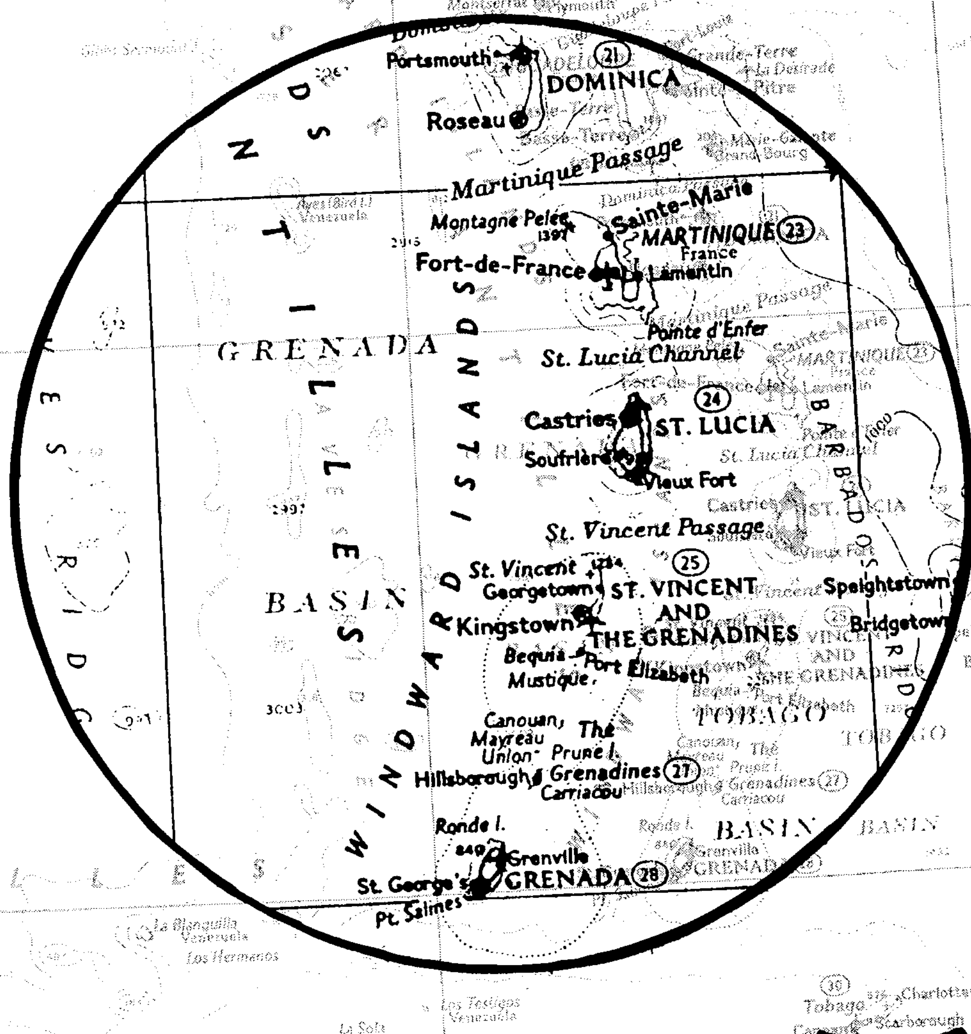
DEVELOPMENT, FORESTRY, AND ENVIRONMENTAL QUALITY IN THE EASTERN CARIBBEAN



An Institute of Tropical Forestry Publication

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Preface

In 1982 the U.S. Agency for International Development contracted the Institute of Tropical Forestry to a five-phase study of five eastern Caribbean islands. This study was to be part of the U.S. government's contribution to the Caribbean Environmental Action Plan. The five phases of the study were:

1. training of young Caribbean foresters,

2. assessments of wildlife in the islands,

3. studies of watersheds in three islands including a forest inventory of Saint Vincent and the Grenadines,

4. analysis of the effects of hurricanes on island forests, and

5. a synthesis of all the above with emphasis on the problems of development and environmental quality in the eastern Caribbean.

This volume contains the final report of three of the five phases i.e., numbers 3, 4, and 5. Results of the other two phases are included in three other volumes: Wildlife Assessments by Faarborg and Arendt, and two volumes that summarize the training courses. One of these contains the materials used for the training courses and the other is a compilation of case studies prepared by course participants.

The first activity under the program was a planning meeting held at the Institute of Tropical Forestry with the purpose of outlining the scope of the study and for establishing procedures for cooperation. After that meeting the U.S. Forest Service, through the Southern Forest Experiment Station, entered into formal agreements with each of the five island governments to facilitate the implementation of the study plan. Island cooperators made the project possible through their good will, enthusiasm, and support of our activities. At all times and without exception the technicians and scientists working in the various phases of the study received excellent support from colleagues in participating islands.

Table 1 contains a time table of all the activities that the Institute of Tropical Forestry engaged in during the execution of this project including a listing of all the people and agencies that made the work possible. These people and institutions are the ones that deserve the credit for making this project a success.

Ariel E. Lugo
Project Leader
Rio Piedras, Puerto Rico
September 14, 1985

Table 1. Time table of activities and listing of personnel involved.

Agency	Personnel	Activity
Department of Agriculture Dunbars - Antigua	R. Anthony	Planning meeting at the Institute of Tropical Forestry
Department of Biology Division of Biological Sciences University of Missouri Colombia, MO 65211	J. Faaborg	
Department of Natural Resources Forest Service P.O. Box 5887 San Juan, PR 00906	D. Jiménez R. Schmidt	
Forestry Division Botanical Garden Roseau, Dominica	F. Gregoire	
Forestry Division Ministry of Agriculture and Trade Kingstown, St. Vincent	C.F. Nicholls	
Island Resources Foundation and Virginia Institute of Marine Science Box 254 Glovester, VA 23061	M. Nichols	
Ministry of Agriculture, Food and Consumer Affairs Graeme Hall Christ Church, Barbados	E. Payne	
The Ministry of Agriculture Forestry Division Castries, St. Lucia	G. Charles	
US Agency for International Development Port-au-Prince, Haiti, or c/o American Embassy Harry Truman Blvd. Port-au-Prince, Haiti	J. Talbot	

Table 1. (cont'd)

Agency	Personnel	Activity
USDA Forest Service Caribbean National Forest P.O. Box AQ Río Piedras, PR 00928	E.D. Maldonado J.E. Muñoz	
USDA Forest Service Southern Forest Experiment Station T-10210, US Postal Services Bldg. 701 Loyola Avenue New Orleans, LA 70113	L.V. Deselle	
USDA Forest Service Southern Forest Experiment Station Institute of Tropical Forestry P.O. Box AQ Río Piedras, PR 00928	W. Arendt L.H. Liegel A.E. Lugo P.L. Weaver	
US Geological Survey Water Resources Division US Department of Interior Box 4424 San Juan, PR 00936	F. Quiñones	
United Nations Environment Programe Polais Des Nations 1211 Geneva 10 Switzerland	A. Rodríguez	
Department of Natural Resources Forest Service P.O. Box 5887 San Juan, PR 00906	J. González-Liboy J. Stewart J. Vivaldi R. Woodbury	First and second training courses for junior Caribbean foresters
Environmental Quality Board P.O. Box 11488 Santurce, PR 00910	L. Matos M. Rivera F. del Valle	
USDA Forest Service Caribbean National Forest Box 21 Palmer, PR 00721	J. Bauer D. Bolinger J. Lefebre M. Maldonado I. Rivera L. Santoyo J. Zambrana	

Table 1. (cont'd)

Agency	Personnel	Activity
USDA Forest Service Caribbean National Forest P.O. Box AQ Río Piedras, PR 00928	E.D. Maldonado J.E. Muñoz	
USDA Forest Service Southern Forest Experiment Station Institute of Tropical Forestry P.O. Box AQ Río Piedras, PR 00928	J.B. Feheley J.C. Figueroa J. Jiménez L.H. Liegel A.E. Lugo C. Rivera F. Torres F.H. Wadsworth P.L. Weaver	
USDA Forest Service Southern Region (R-8) 1720 Peachtree Road, N.W. Atlanta, GA 30367	G. Dissmeyer	
US Fish and Wildlife Service Luquillo Experimental Forest Box 21 Palmer, PR 00721	J. Wiley	
US Geological Survey Water Resources Division US Department of Interior Box 4424 San Juan, PR 00936	P. McKinley	
US Soil Conservation Service G.P.O. Box 4868 San Juan, PR 00936	A. Sierra	
Collaborator (San Juan, PR)	J. Rodríguez Vidal	
Antigua Archaeological Society St. Johns, Antigua	D.V. Nicholson	Wildlife assessments in Caribbean islands
Department of Agriculture Dunbars, Antigua	R. Williams	

Table 1. (cont'd)

Agency	Personnel	Activity
Department of Biology Division of Biological Sciences University of Missouri Colombia, MO 65211	M. Davis J. Faaborg J. Faaborg S. King	
Forestry Division Botanical Garden Roseau, Dominica	F. Gregoire C.C. Maximea	
Forestry Division Ministry of Agriculture and Trade Kingstown, St. Vincent	C.F. Nicholls	
Ministry of Agriculture, Food and Consumer Affairs Graeme Hall Christ Church, Barbados	E. Payne	
Ministry of Agriculture Plymouth, Montserrat	W. Johnson	
Ministry of Agriculture, Lands, Housing and Development Basseterre, St. Kitts	R. Wilkin V. Williams K. Martin E. Petty	
The Ministry of Agriculture Forestry Division Castries, St. Lucia	P. Butler G. Charles	
US Agency for International Development Port-au-Prince, Haiti, or c/o American Embassy Harry Truman Blvd. Port-au-Prince, Haiti	J. Talbot	
USDA Forest Service Southern Forest Experiment Station Institute of Tropical Forestry P.O. Box AQ Río Piedras, PR 00928	A. Arendt W. Arendt A.E. Lugo	

Table 1. (cont'd)

Agency	Personnel	Activity
USDA Forest Service Southern Forest Experiment Station Forestry Sciences Laboratory Box 906 Starkville, MS 39759	W. Cleckley	
Wider Caribbean Sea Turtle Recovery Team St. Johns, Antigua	J. Fuller	
Collaborator	D. Gibbs	
USDA Forest Service Southern Forest Experiment Station Institute of Tropical Forestry P.O. Box AQ Rio Piedras, PR 00928	A.E. Lugo	Watershed planning trip to the islands
US Geological Survey Water Resources Division US Department of Interior Box 4424 San Juan, PR 00936	R. Curtis	
	P. Díaz F. Hernández L. Santiago	Preparing and shipping of river gaging stations
	R. Curtis P. Díaz G. Arroyo	Installation of river gaging and rainfall stations and training for collection of water samples and operation of stations
Center for Energy and Environment Research Terrestrial Ecology Division G.P.O. Box 3682 San Juan, PR 00936	W. McDowell	

Table 1. (cont'd)

Agency	Personnel	Activity
US Geological Survey Water Resources Division US Department of Interior	G. Arroyo P. Díaz	Visits to maintain river gaging and rainfall stations.
	Routine station operation and water sampling by island forestry personnel including G. Cordice in St. Vincent and A. James in Dominica	
	I.M. Concepción R. Curtis P. Díaz Z. Díaz L. Santiago	Analysis of watershed data.
Forestry Division Botanical Garden Roseau, Dominica	A. Gallion F. Gregoire A. James S. John M. Metor R. Winston	Field work on documentation of hurricane damage to forests
The Ministry of Agriculture Forestry Division Castries, St. Lucia	M. Andrew M. Bobb W. Felix	
USDA Forest Service Southern Forest Experiment Station Institute of Tropical Forestry P.O. Box AQ Río Piedras, PR 00928	A.E. Lugo A. Rodríguez	
	L.H. Liegel A.E. Lugo A. Rodríguez	Analysis of data on hurricane effects on forests
	P.L. Weaver	Forest inventory planning trip to St. Vincent and the Grenadines
USDA Forest Service Southern Forest Experiment Station Forestry Sciences Laboratory Box 906 Starkville, MS 39759	R.A. Birdsey	

Table 1. (cont'd)

Agency	Personnel	Activity
Forestry Division Ministry of Agriculture and Trade Kingstown, St. Vincent	G. Beache E. Connor G. Cordice C.F. Nicholls L. Quammie J.T. Valenta	Inventory of plantations in St. Vincent and the Grenadines
USDA Forest Service Southern Forest Experiment Station Institute of Tropical Forestry P.O. Box AQ Río Piedras, PR 00928	C. Rivera P.L. Weaver	
USDA Forest Service Southern Forest Experiment Station Forestry Sciences Laboratory Box 906 Starkville, MS 39759	W. Cleckley R.A. Birdsey	
Forestry Division Ministry of Agriculture and Trade Kingstown, St. Vincent	G. Beache E. Connor G. Cordice L. Quammie J.T. Valenta	Field work for forest inventory
USDA Forest Service Southern Forest Experiment Station Institute of Tropical Forestry P.O. Box AQ Río Piedras, PR 00928	C. Rivera	
USDA Forest Service Southern Forest Experiment Station Forestry Sciences Laboratory Box 906 Starkville, MS 39759	W. Cleckley	
USDA Forest Service Southern Forest Experiment Station Institute of Tropical Forestry P.O. Box AQ Río Piedras, PR 00928	P.L. Weaver	Analysis of forest inventory data

Table 1. (cont'd)

Agency	Personnel	Activity
USDA Forest Service Southern Forest Experiment Station Forestry Sciences Laboratory Box 906 Starkville, MS 39759	R.A. Birdsey	

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GENERAL HYDROLOGY AND WATER QUALITY OF THREE RIVERS IN THE EASTERN CARIBBEAN

Pedro L. Diaz
Ariel E. Lugo
William H. McDowell

Introduction

One of the most critical problems facing Caribbean islands is the management of degraded forest lands and watersheds. Forests perform an important role in the process of controlling erosion and sedimentation which, in turn, can affect downstream ecosystems by contaminating water resources. Yet, the information on river discharge, sediments in water, and water quality is generally lacking for Caribbean islands (Lugo, this volume).

An investigation was designed to collect and analyze base data on streamflow, water quality, and rainfall in selected watersheds in Dominica, St. Vincent and St. Lucia (Fig. 1). The study began in 1983 and at the time of this writing (October, 1985) measurements were still in progress. Streamflow and rainfall data were collected continuously, while water-quality samples were collected weekly and during special hydrologic events. The study is part of a cooperative effort for hydrologic-data collection between the Institute of Tropical Forestry (U.S. Forest Service), the U.S. Agency for International Development (USAID), the Water Resources Division of the U.S. Geological Survey, the U.S. Man and the Biosphere Program, and the government of each island. This report covers the period between March 1984 and July 1985.

Geographic and Physiographic Setting

The Caribbean Islands of Dominica, St. Lucia, and St. Vincent are located approximately 500 miles southeast of San Juan, Puerto Rico (Fig. 1). These islands, of volcanic formation, are characterized by a steep topography which results in rapid runoff and relatively straight shallow streams.

The climate of the islands is tropical with relatively high rainfall. Rainfall varies from 60 in/yr in the coastal areas to about 200 in/yr in the interior. The islands are located in the path of tropical storms which normally occur from July to November. During this time of year rainfall of high intensity can occur. The dry season is from January to April while the wet season extends from May to November.

A watershed representative of the general hydrology was selected on each inland. The contributing drainage area for the streamflow stations included in the study are as follows: Layou River in Dominica 27.1 mi^2; Buccament in St. Vincent 7.12 mi^2; and the Troumassee River in St. Lucia 5.44 mi^2. The three rivers have gradients ranging from 152 ft/mi in Layou

River to 339 ft/mi in Buccament River (Fig. 2). Land uses at all three watersheds include forest, agriculture, and rural housing. However, the Buccament River is the most intensively developed of the three watersheds, and the Layou River the least in terms of land use.

The objective of the study was to define the annual variation of principal chemical constituents of river waters and suspended sediment concentrations with changes in streamflow. Continuously-recording gages were established on each watershed to monitor streamflow and rainfall. Water samples were collected on a regular basis for sediment and chemical analyses. Water samples taken by the Department of Agriculture, Forestry Division personnel, on each island were analyzed by the Center for Energy and Environmental Research at Rio Piedras, Puerto Rico. The USGS Laboratory measured the sediment content of waters.

Water Quality

Average values for about 30-40 samples analyzed from each island are summarized in Table 1. The quality of the water is generally good and typical of a tropical forest except for nitrates and ammonia in the Buccament River, which are higher in comparison with the other two rivers but comparable to Rio Fajardo, Puerto Rico.

Sediment concentrations range from 0 to 490 mg/ℓ on Layou River; from 2 to 654 mg/ℓ on Buccament River; and from 0 to 320 mg/ℓ on Troumassee River.

Hydrology

Figures 3-5 show the annual pattern of river discharge in the three study areas and the Tables in the Appendix give daily, total, mean, minimum, and maximum monthly discharge values. The Appendix tables also provide information on the location, elevation, and drainage area of each station. The data show that the Layou River had the largest drainage area and highest mean monthly discharge and discharge per unit area (Table 2). The two other rivers had similar discharge characteristics and were comparable to the Rio Fajardo in Puerto Rico.

As is expected of rivers from steep moist tropical islands, rivers exhibited rapid changes in stage associated with rainfall events. Figure 6 illustrates the close relation between rainfall and river discharge in the Layou River.

As river discharge increases there is a proportional increase in the sediment load in riverine waters (Fig. 7). The relation is similar in slope for the Buccament and the Troumassee Rivers but the slope for the Layou River was steeper than the others in spite of its larger discharge. The relation between sediment yield (y, in t/day) and river discharge (x, in ft^3/s) for the Layou, Troumassee, and Buccament Rivers were (respectively): $y = 1.29x - 343$ ($r^2 = 0.84$), $y = 0.67x - 11$ ($r^2 = 0.85$), and $y = 0.62x - 20$ ($r^2 = 0.79$). The Layou River transports more sediment than the other two rivers because it has a larger drainage area and discharges more water. However, based on a unit area or unit river discharge, this watershed yields a lower quantity of sediment than the other two rivers. We attribute this to the greater proportion of forest area in the Layou River watershed.

Discussion

Relatively high rainfall, small drainage areas, and steep slopes contribute to the high streamflow of the three rivers in the Caribbean Islands of Dominica, St. Vincent, and St. Lucia. Concentrations of chloride and silicate are typical of tropical rain forest streams. With the exception of nitrate and ammonia - N in the Buccament River, nutrient concentrations are generally low. Higher nitrogen concentrations in Buccament River are presumably due to higher population density along the rivers edge in St. Vincent, and use of the stream for bathing and washing clothes. Sediment yields are low on a unit area basis for the Layou River watershed which has a large forest area and higher for the more developed watersheds in Saint Lucia and Saint Vincent. However, all rivers yield more sediments with increasing water discharge and sediment yields can be as high as about 3,000 t/day.

The data from the investigation will be used as input for the construction and calibration of digital rainfall-sediment model at the conclusion of the data collection phase of the project. The final results will be useful to land and water resources management on the islands.

Literature Cited

U.S. Geological Survey. 1983. Water resources data for Puerto Rico and the U.S. Virgin Islands water year 1983. U.S. Geological Survey Water Data Report PR-83-1, 302 p.

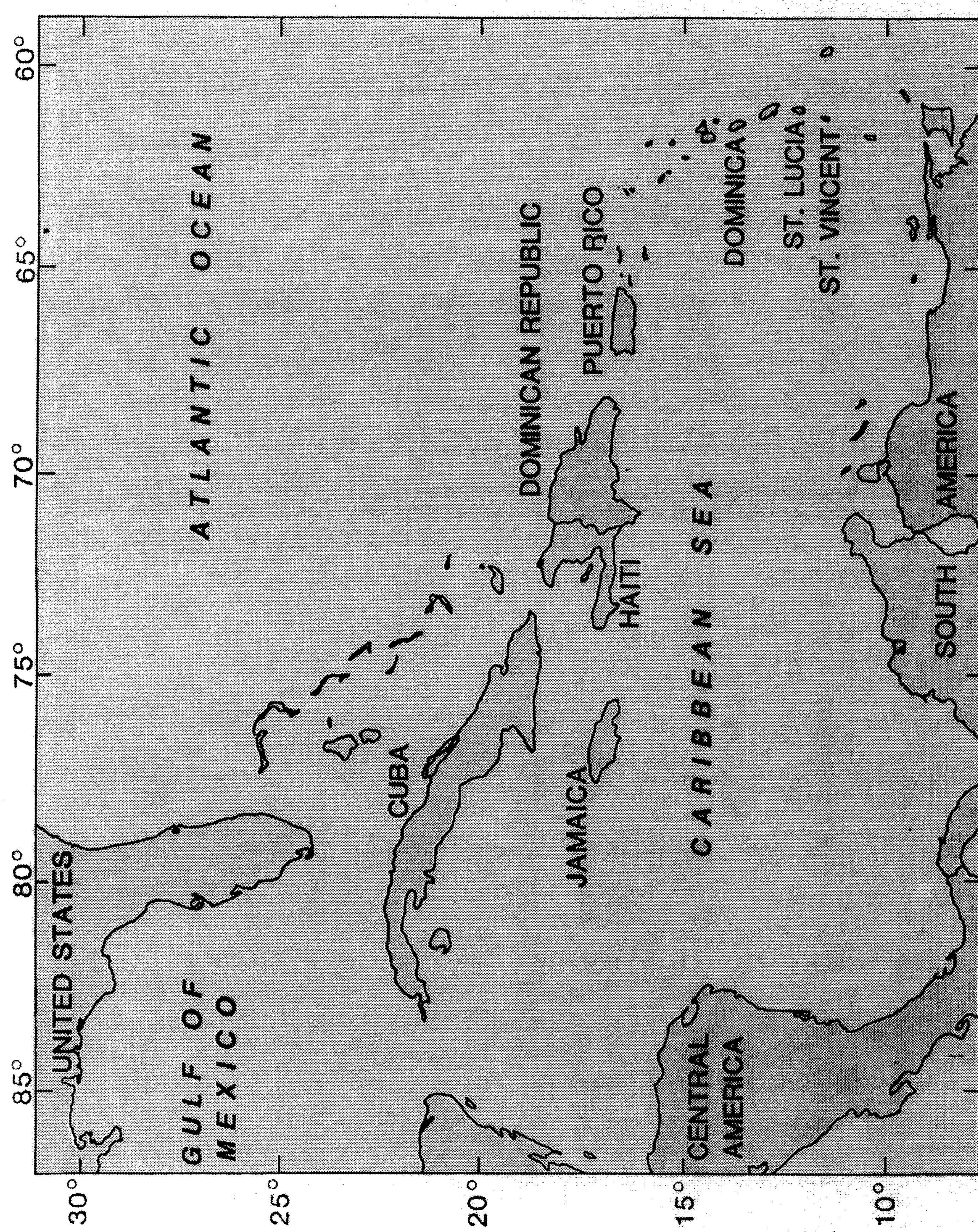
Table 1. Average values for selected chemical constituents at Layou, Buccament, and Troumassee Rivers, and Rio Fajardo in Puerto Rico.

River	Cloride dissolved (mg/ℓ as CL)	Silica dissolved (mg/ℓ as SiO_2)	Nitrogen Nitrate (mg/ℓ as N)	Nitrogen Ammonia (mg/ℓ as N)	Total dissolved Phosphorus (μg/ℓ)
Layou River in Dominica	9.6	32	0.051	0.017	12
Buccament River in St. Vincent	8.1	32	0.191	0.147	6
Troumassee River in St. Lucia	13.3	26	0.035	0.015	6
Rio Fajardo, Puerto Rico	10.6	23	0.241	0.031	-

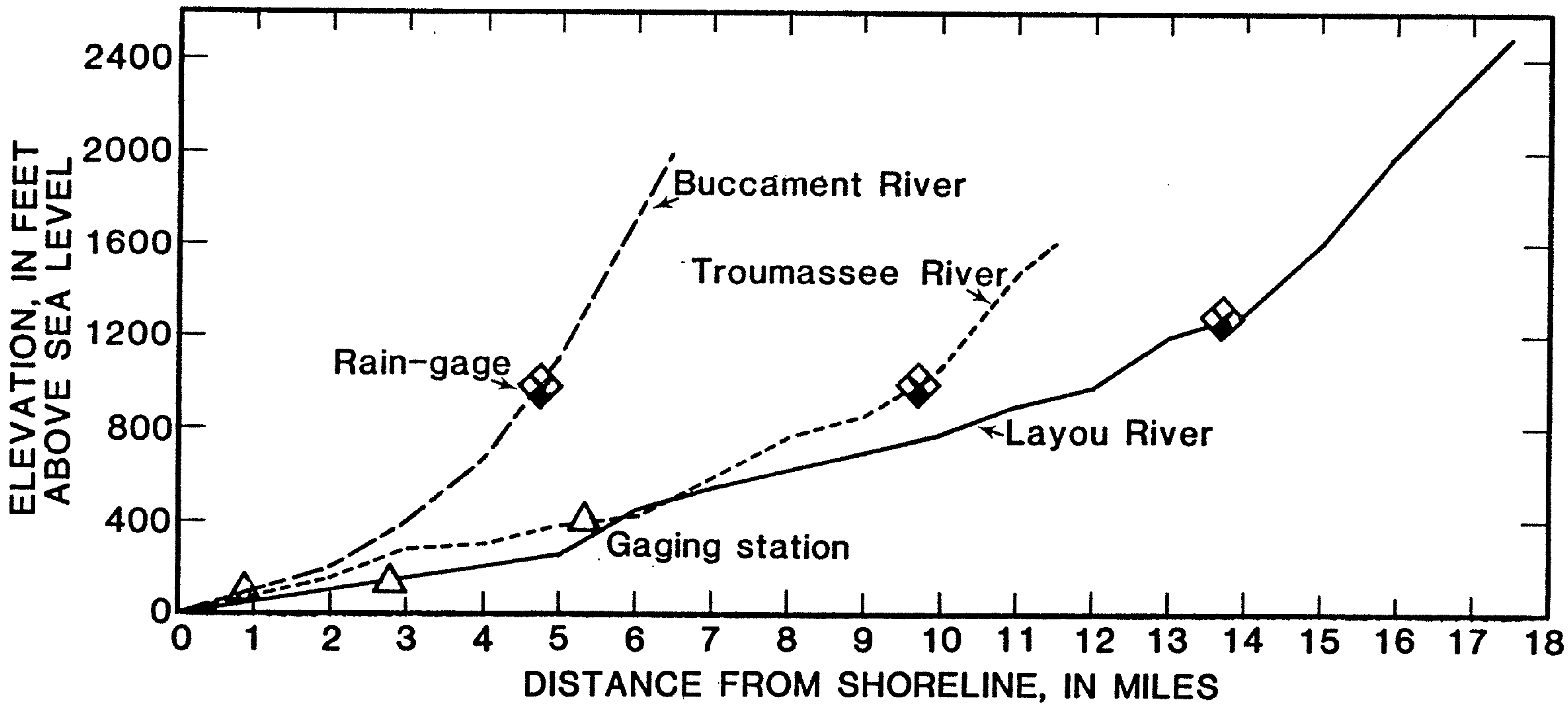
Table 2. Stream discharge by unit drainage area.

Stream	Drainage area (mi^2)	Mean monthly discharge (Qm) (ft^3/s)*	Discharge per unit ($ft^3/s.mi^2$)*
Layou River, Dominica	27.1	233.0	8.60
Buccament River, St. Vincent	7.12	25.5	3.58
Troumassee River, St. Lucia	5.44	23.3	4.29
Río Fajardo, Puerto Rico	14.9	55.6	3.73

* Same period of record used in comparison (March 1984 to June 1985).

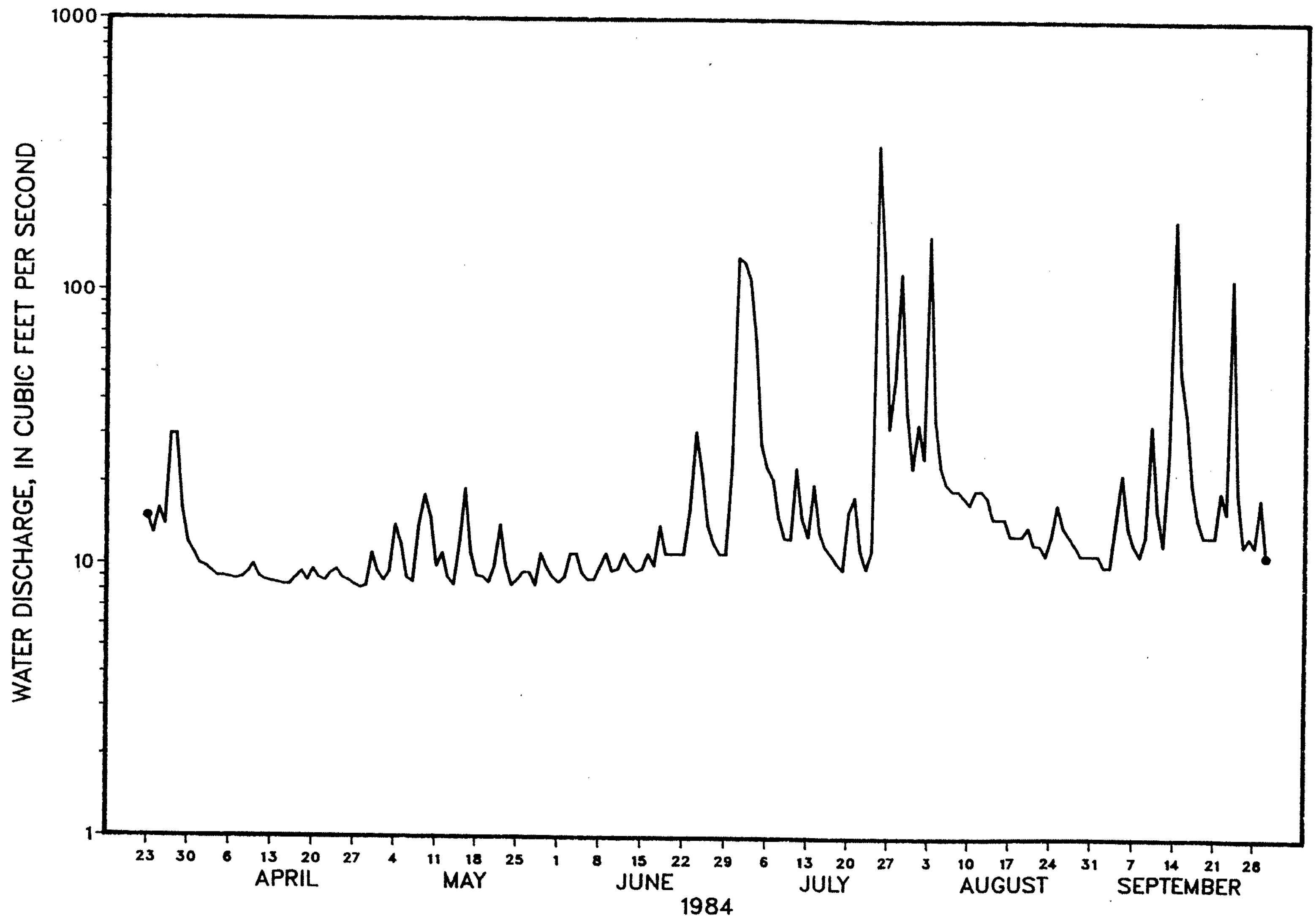


UNITED STATES
GULF OF MEXICO
ATLANTIC OCEAN
CUBA
JAMAICA
HAITI
DOMINICAN REPUBLIC
PUERTO RICO
DOMINICA
ST. LUCIA
ST. VINCENT
CARIBBEAN SEA
CENTRAL AMERICA
SOUTH AMERICA
85°
80°
75°
70°
65°
60°
30°
25°
20°
15°
10°

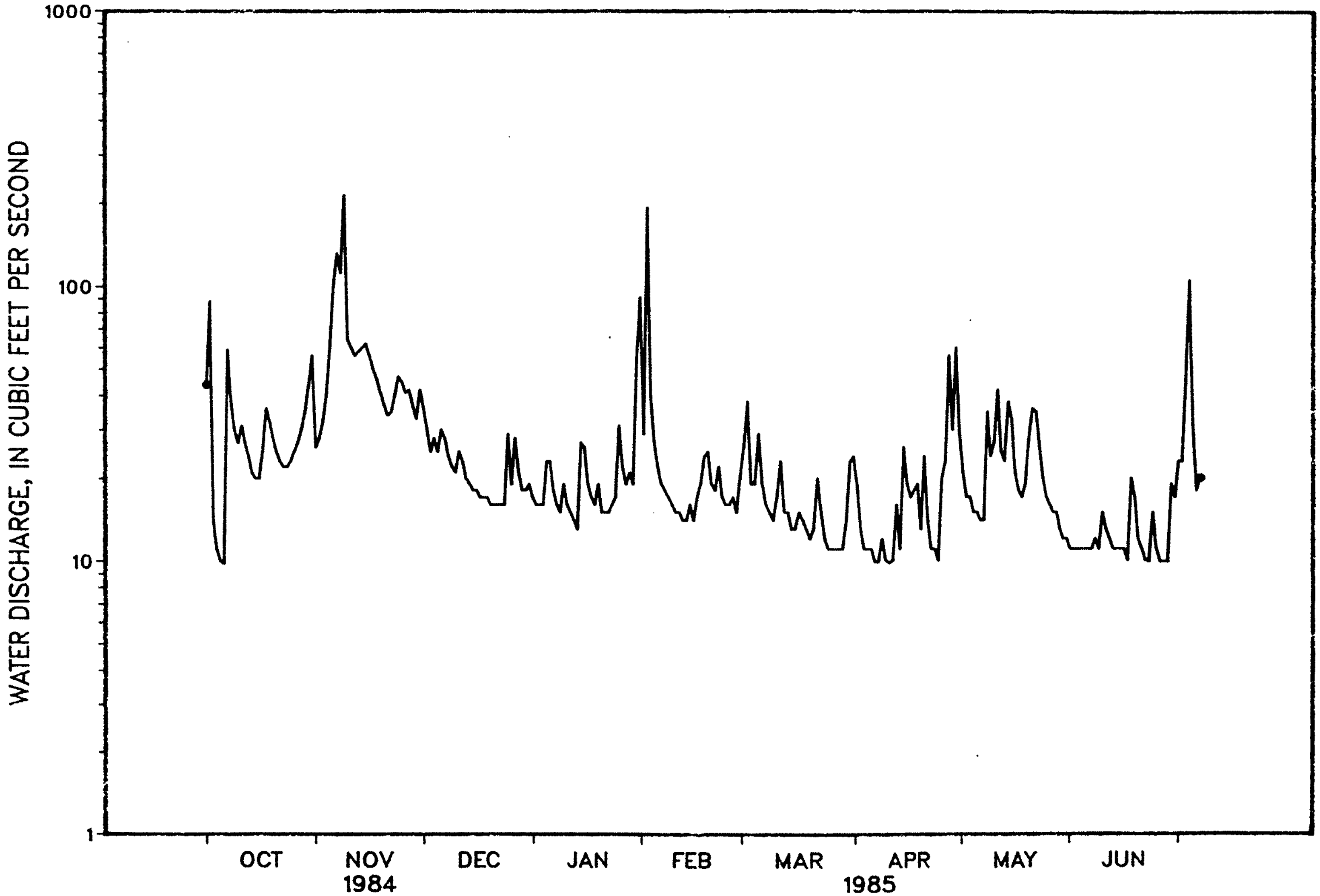


Channel profiles of Layou River at Dominica, Troumassee River at St. Lucia and Buccament River at St. Vincent.

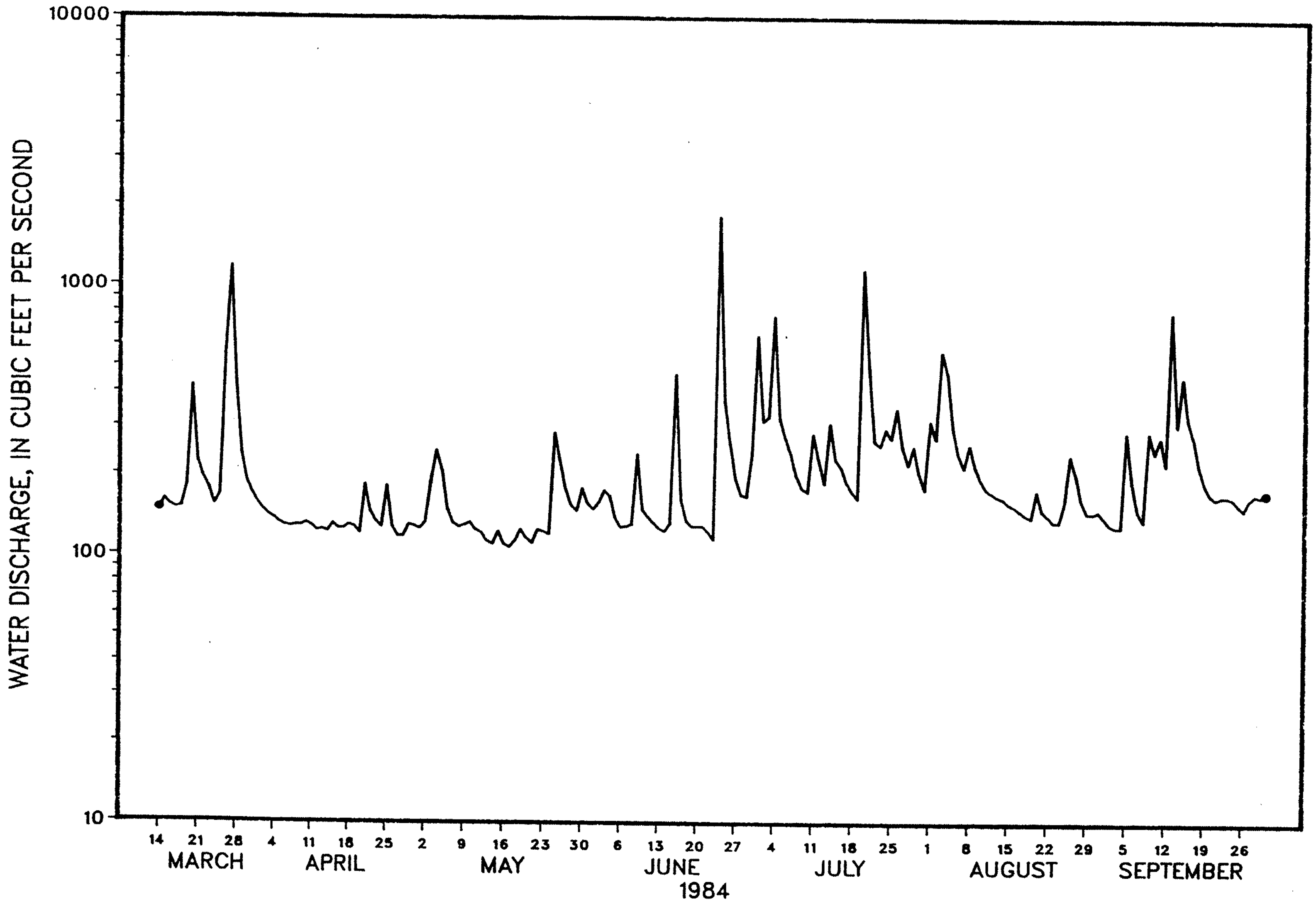
135022060572400 TROUMASSEE RIVER AT MAHAUT, ST. LUCIA, W.I.
WATER YEAR 1984



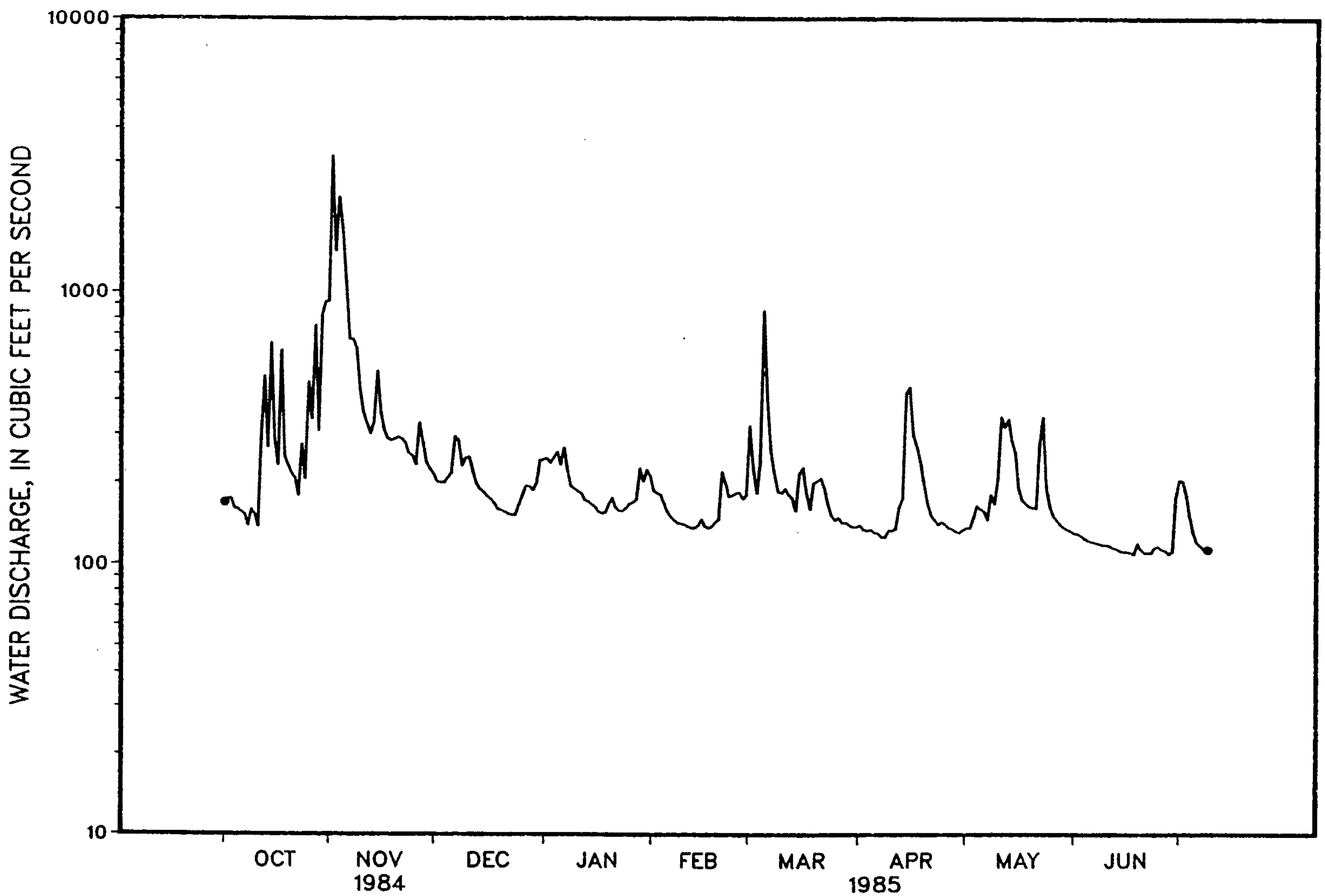
135022060572400 TROUMASSEE RIVER AT MAHAUT, ST. LUCIA, W.I.
WATER YEAR 1985



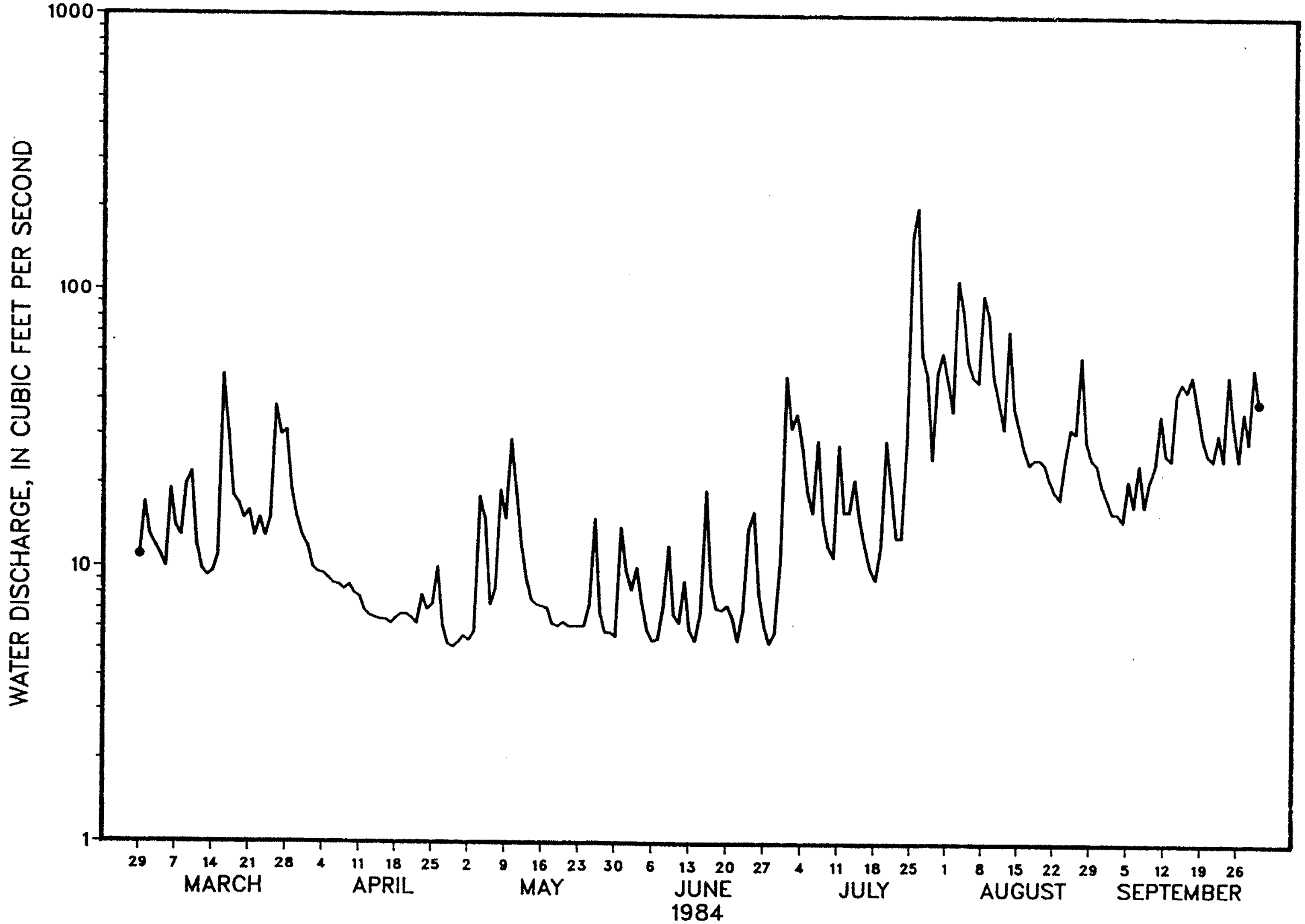
152450061234400 LAYOU RIVER AT LAYOU VALLEY, DOMINICA, W.I.
WATER YEAR 1984



15245006123440O LAYOU RIVER AT LAYOU VALLEY, DOMINICA, W.I.
WATER YEAR 1985



13113506015330 BUCCAMENT RIVER AT PEMBROKE, ST. VINCENT, W.I.
WATER YEAR 1984



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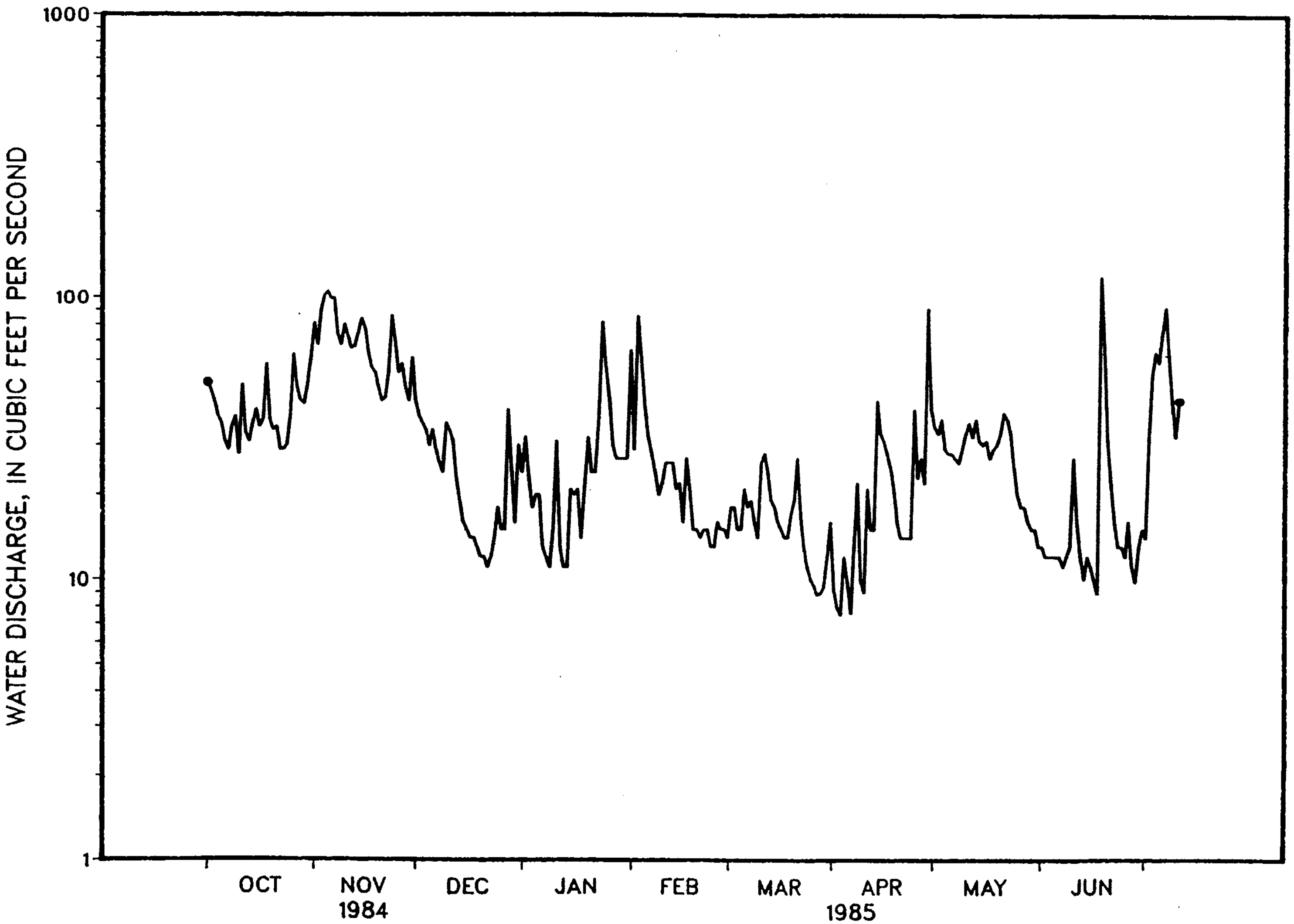
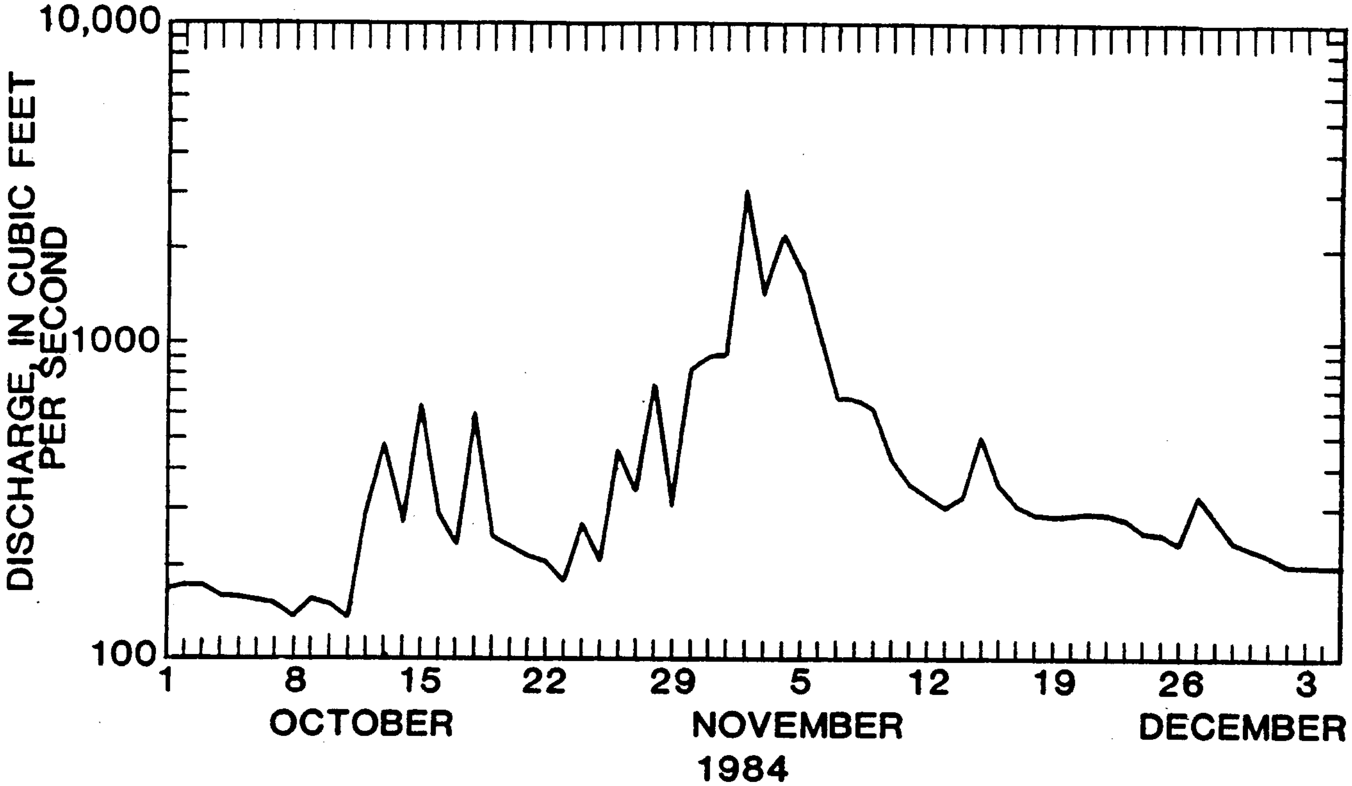
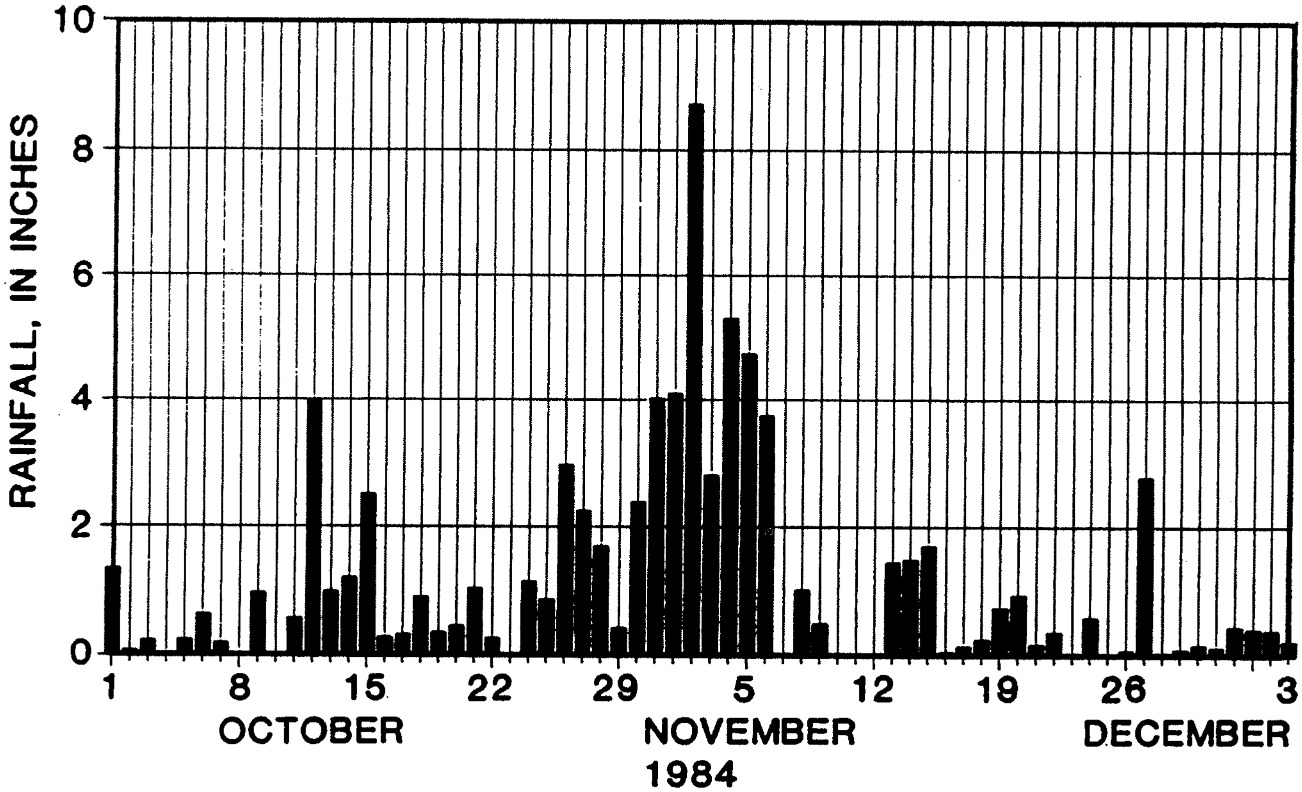
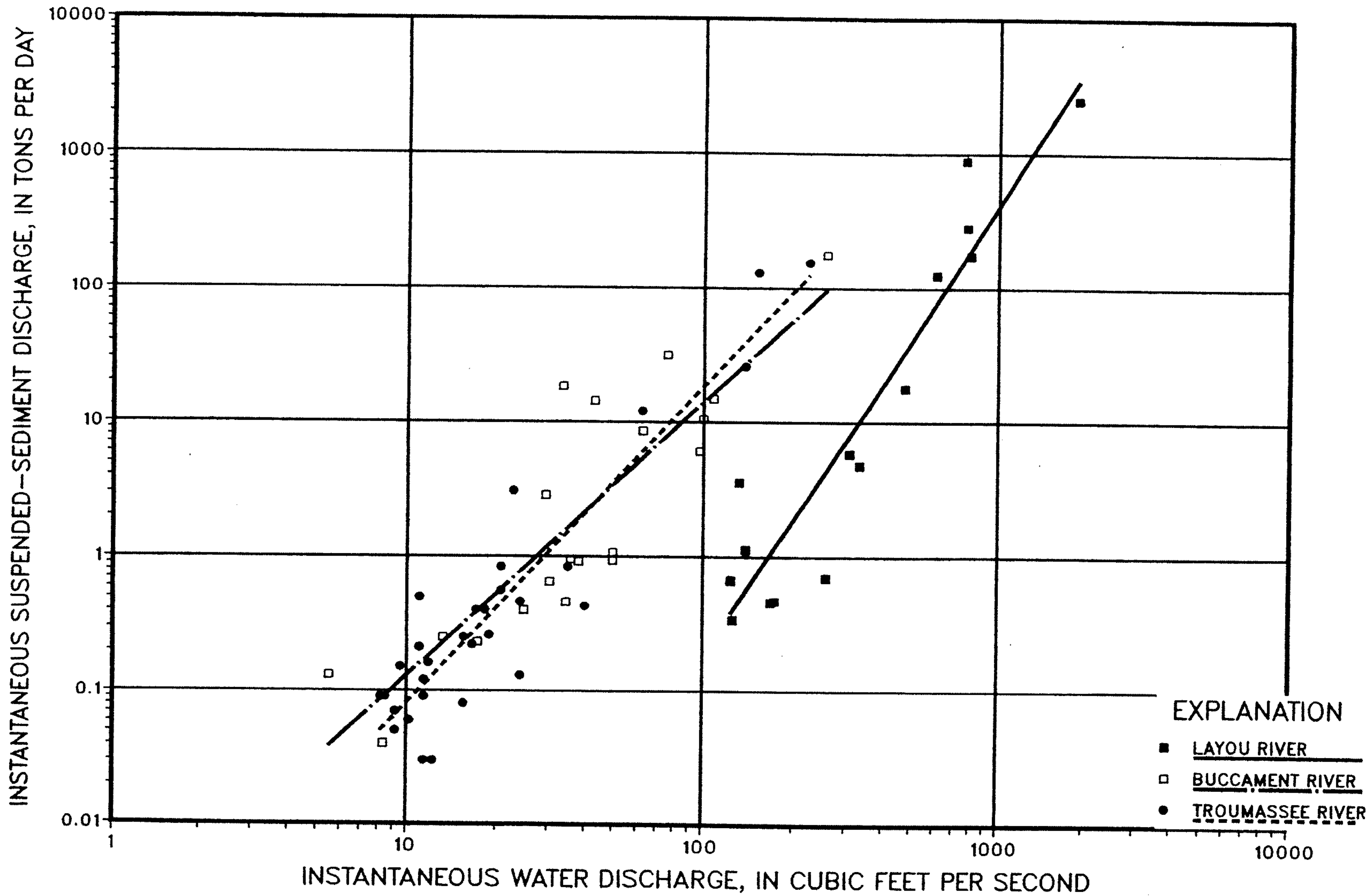
WATER YEAR 1985







Rainfall-Runoff relation at Layou River basin during October and November 1984.



INSTANTANEOUS SUSPENDED-SEDIMENT DISCHARGE, IN TONS PER DAY
10000
1000
100
10
1
0.1
0.01
1
10
100
1000
10000
INSTANTANEOUS WATER DISCHARGE, IN CUBIC FEET PER SECOND
EXPLANATION
LAYOU RIVER
BUCCAMENT RIVER
TROUMASSEE RIVER

152450061234400 LAYOU RIVER AT LAYOU VALLEY, DOMINICA, W.I.

LOCATION.--Lat. 15°24'50", long 61°23'44", at highway bridge 3.2 mi (8.3 km) northeast from Layou village and 0.64 mi (1.6 km) north of York Valley Estate.

DRAINAGE AREA.--27.1 sq mi (70.2 sq km).

WATER-DISCHARGE RECORDS

PERIOD OF RECORD.--March 1984 to current year.

GAGE.--Water-stage recorder. Altitude of gage is about 150 ft. (45.7 m) above mean sea level, from topographic map.

REMARKS.--Records fair.

EXTREMES FOR WATER YEARS 1984-85.--Peak discharges above base of 3,000 cu ft/s (85.0 cu m/s) and maximum (*):

Date	Time	Discharge (cu ft/s)	Discharge (cu m/s)	Gage height (ft)	Gage height (m)
Mar. 26, 1984	2215	4020	114	7.25	2.210
Mar. 27	0130	4150	118	7.35	2.240
June 24	1430	15600	442	13.20	4.023
July 20	1200	5540	157	8.35	2.545
Oct. 18, 1984	0430	3210	90.9	6.56	1.999
Oct. 30	1245	5900	167	8.59	2.618
Nov. 2	0715	7730	219	9.68	2.950
Nov. 4	0615	5610	159	8.40	2.560

Minimum discharges, 105 cu ft/s (2.974 cu m/s) May 17, 1984; 108 cu ft/s (3.058 cu m/s), June 18-19, 22-24, 28-30, 1985.

ST. VICENT, LESSER ANTILLES

131135060153300 BUCCAMENT RIVER AT PEMBROKE, ST. VICENT, W.I.

LOCATION.--Lat. 13°11'35", long 60°15'33", at highway bridge 1.8 mi (2.9 km) northwest of Kingstown and 0.5 mi (0.8 km) southwest of Pembroke.

DRAINAGE AREA.--7.12 sq mi (18.4 sq km).

WATER-DISCHARGE RECORDS

PERIOD OF RECORD.--February 1984 to current year.

GAGE.--Water-stage recorder. Altitude of gage is about 100 ft. (30.5 m) above mean sea level, from topographic map.

REMARKS.--Records fair. Discharge for period of no gage-height record (July 27 to August 17, 1984) were estimated on the basis of records from Troumassee River at Mahaut, St. Lucia, W.I. for the same period of record and observer's gage height readings.

EXTREMES FOR WATER YEARS 1984-85.--Peak discharges above base of 300 cu ft/s (8.50 cu m/s) and maximum (*):

Date	Time	Discharge (cu ft/s)	Discharge (cu m/s)	Gage height (ft)	Gage height (m)	Date	Time	Discharge (cu ft/s)	Discharge (cu m/s)	Gage height (ft)	Gage height (m)
July 25, 1984	2230	703	19.9	3.90	1.189	Sept. 24, 1984	1545	317	8.98	2.66	0.811
July 26	0800	745	21.1	4.01	1.222	Apr. 26, 1985	1515	302	8.55	2.60	0.792
Aug. 3	1000	609	17.2	3.64	1.109	June 19	1330	478	13.5	3.24	0.988

Minimum discharges, 4.3 cu ft/s (0.122 cu m/s) June 23, 1984; 6.7 cu ft/s (.190 cu m/s) Apr. 8, 1985.

131135060153300 BUCCAMENT RIVER AT PEMBROKE, ST. VINCENT
LAT 131135 LONG 0601533 STATE 76 COUNTY 111 DRAINAGE AREA: 7.12

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1983 TO SEPTEMBER 1984
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1					---	17	12	5.6	9.8	49	42	18
2					---	13	10	5.4	8.3	32	35	16
3					---	12	9.6	5.8	10	36	110	16
4					---	11	9.5	18	7.4	28	50	15
5					---	10	9.1	15	5.9	19	37	21
6					---	19	8.7	7.3	5.4	16	33	17
7					---	14	8.6	8.3	5.5	29	31	24
8					---	13	8.3	19	7.2	15	31	17
9					---	20	8.6	15	12	12	28	21
10					---	22	8.0	29	6.7	11	27	24
11					---	12	7.8	19	6.3	28	31	36
12					---	9.8	6.9	12	8.9	16	31	26
13					---	9.3	6.6	9.0	5.9	16	28	25
14					---	9.6	6.5	7.6	5.4	21	26	43
15					---	11	6.4	7.3	6.8	15	25	47
16					---	49	6.4	7.2	19	12	25	44
17					---	31	6.2	7.1	8.6	10	25	50
18					---	18	6.5	6.2	7.1	9.1	25	39
19					---	17	6.7	6.1	7.0	12	25	30
20					---	15	6.7	6.3	7.3	29	24	26
21					---	16	6.5	6.1	6.6	20	21	25
22					---	13	6.2	6.1	5.4	13	19	31
23					---	15	7.9	6.1	6.9	13	18	25
24					---	13	7.0	6.1	14	29	25	50
25					---	15	7.3	7.3	16	158	32	33
26					---	38	10	15	8.1	202	31	25
27					---	30	6.1	6.8	6.2	28	58	37
28					---	31	5.2	5.8	5.3	36	29	29
29					11	19	5.1	5.8	5.8	25	25	53
30					---	15	5.3	5.6	11	40	24	40
31					---	13	---	14	---	32	20	---
TOTAL					---	550.7	225.7	300.9	245.8	1011.1	991	903
MEAN					---	17.8	7.52	9.71	8.19	32.6	32.0	30.1
MAX					---	49	12	29	19	202	110	53
MIN					---	9.3	5.1	5.4	5.3	9.1	18	15
CFSM					---	2.50	1.06	1.36	1.15	4.58	4.49	4.23
IN.					---	2.88	1.18	1.57	1.28	5.28	5.18	4.72
AC-FT					---	1090	448	597	488	2010	1970	1790

1985 WY UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION

131135060153300 BUCCAMENT RIVER AT PEMBROKE, ST. VINCENT
LAT 131135 LONG 0601533 STATE 76 COUNTY 111 DRAINAGE AREA: 7.12

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1984 TO SEPTEMBER 1985
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	50	81	43	24	65	14	16	40	13	15		
2	47	68	38	32	29	18	9.2	35	13	14		
3	43	90	36	23	86	18	7.9	33	12	32		
4	38	102	34	18	62	15	7.5	37	12	53		
5	36	105	30	20	41	15	12	29	12	64		
6	31	99	34	20	32	21	9.8	28	12	59		
7	29	99	29	13	28	18	7.6	28	12	75		
8	35	74	26	12	24	19	13	27	11	92		
9	38	68	24	11	20	16	22	26	12	62		
10	28	80	36	15	22	14	9.9	29	13	42		
11	49	73	34	31	26	26	9.0	33	27	32		
12	33	66	31	13	26	28	21	36	16	43		
13	31	67	23	11	26	24	15	32	12	---		
14	36	75	19	11	21	19	15	37	10	---		
15	40	84	16	21	22	18	43	31	12	---		
16	35	78	15	20	16	16	33	30	11	---		
17	37	64	14	21	27	15	31	31	9.9	---		
18	58	56	14	14	21	14	28	27	8.9	---		
19	37	54	13	21	15	14	25	29	118	---		
20	34	48	12	32	15	17	21	30	68	---		
21	35	43	12	24	14	19	16	33	31	---		
22	29	44	11	24	15	27	14	39	22	---		
23	29	54	12	38	15	17	14	37	16	---		
24	30	86	14	82	13	13	14	33	13	---		
25	38	70	18	57	13	11	14	25	13	---		
26	63	54	15	44	16	10	40	20	12	---		
27	48	58	15	30	15	9.5	23	18	16	---		
28	43	48	40	27	15	8.8	27	18	11	---		
29	42	43	25	27	---	8.9	22	16	9.8	---		
30	49	61	16	27	---	9.4	91	15	13	---		
31	61	---	30	27	---	12	---	15	---	---		
TOTAL	1232	2092	729	790	740	504.6	630.9	897	571.6	---		
MEAN	39.7	69.7	23.5	25.5	26.4	16.3	21.0	28.9	19.1	---		
MAX	63	105	43	82	86	28	91	40	118	---		
MIN	28	43	11	11	13	8.8	7.5	15	8.9	---		
CFSM	5.58	9.79	3.30	3.58	3.71	2.29	2.95	4.06	2.68	---		
IN.	6.44	10.93	3.81	4.13	3.87	2.64	3.30	4.69	2.99	---		
AC-FT	2440	4150	1450	1570	1470	1000	1250	1780	1130	---		

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION

152450061234400 LAYOU RIVER AT LAYOU VALLEY, DOMINICA
LAT 152450 LONG 0612344 STATE 76 COUNTY 111 DRAINAGE AREA: 27.1

PROVISIONAL DATA DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1983 TO SEPTEMBER 1984
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1						---	156	126	149	654	317	140
2						---	147	133	158	316	275	132
3						---	141	188	175	328	571	129
4						---	137	245	167	774	477	129
5						---	132	208	138	322	299	290
6						---	129	148	128	276	240	190
7						---	128	132	129	240	215	148
8						---	129	128	131	199	260	136
9						---	129	130	239	179	216	290
10						---	132	133	148	174	192	244
11						---	129	125	140	285	178	278
12						---	124	122	133	229	173	221
13						---	125	113	127	187	168	804
14						149	123	110	124	311	165	308
15						161	131	123	132	229	158	461
16						153	126	110	470	215	154	321
17						149	126	107	162	188	148	278
18						151	130	113	135	174	143	218
19						181	128	125	129	165	140	187
20						420	121	116	129	1150	176	172
21						223	183	111	129	498	148	166
22						194	145	125	123	268	142	169
23						178	134	123	115	258	135	169
24						154	128	120	1820	297	135	167
25						168	181	286	374	275	160	158
26						579	128	225	262	353	238	151
27						1170	118	177	193	255	203	165
28						430	118	154	169	220	163	172
29						236	130	147	167	256	146	170
30						187	129	178	239	204	145	173
31						169	---	156	---	178	148	---
TOTAL						---	4017	4537	6834	9657	6428	6736
MEAN						---	134	146	228	312	207	225
MAX						---	183	286	1820	1150	571	804
MIN						---	118	107	115	165	135	129
CFSM						---	4.94	5.39	8.41	11.5	7.64	8.30
IN.						---	5.51	6.23	9.38	13.26	8.82	9.25
AC-FT						---	7970	9000	13560	19150	12750	13360

1985 WY UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION

152450061234400 LAYOU RIVER AT LAYOU VALLEY, DOMINICA
LAT 152450 LONG 0612344 STATE 76 COUNTY 111

DRAINAGE AREA: 27.1

PROVISIONAL DATA DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1984 TO SEPTEMBER 1985
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	168	920	214	241	211	178	136	133	131	176		
2	174	3140	200	243	185	320	138	135	129	203		
3	173	1410	199	235	181	224	133	135	128	201		
4	160	2230	199	245	179	181	132	147	126	179		
5	159	1710	208	257	167	235	133	163	123	148		
6	155	1090	216	231	155	849	130	159	121	129		
7	152	668	293	267	149	400	129	156	120	119		
8	138	664	284	219	144	256	125	145	119	116		
9	158	621	229	192	141	213	125	179	118	112		
10	152	435	244	188	140	183	132	166	117	112		
11	137	360	246	184	139	181	132	204	117	---		
12	297	327	220	181	137	188	134	347	116	---		
13	487	301	197	171	135	179	161	317	114	---		
14	269	329	187	169	135	174	173	339	113	---		
15	647	509	183	165	138	156	426	284	111	---		
16	287	358	177	162	145	215	445	256	110	---		
17	231	306	173	155	137	225	296	187	110	---		
18	608	288	167	153	135	180	270	171	109	---		
19	246	284	159	154	137	158	235	166	108	---		
20	230	288	157	166	142	198	194	162	118	---		
21	215	292	155	174	145	201	166	161	112	---		
22	207	288	152	161	218	206	150	160	109	---		
23	178	278	151	156	198	190	144	274	109	---		
24	275	254	151	156	176	166	139	345	109	---		
25	206	249	164	160	178	150	142	189	114	---		
26	465	232	178	166	181	144	139	162	115	---		
27	340	329	193	168	182	147	135	149	112	---		
28	749	281	192	172	173	141	134	143	111	---		
29	308	235	186	224	---	141	131	138	108	---		
30	820	223	198	201	---	138	130	135	110	---		
31	913	---	239	221	---	136	---	133	---	---		
TOTAL	9704	18899	6111	5937	4483	6653	5189	5940	3467	---		
MEAN	313	630	197	192	160	215	173	192	116	---		
MAX	913	3140	293	267	218	849	445	347	131	---		
MIN	137	223	151	153	135	136	125	133	108	---		
CFSM	11.5	23.2	7.27	7.08	5.90	7.93	6.38	7.08	4.28	---		
IN.	13.32	25.94	8.39	8.15	6.15	9.13	7.12	8.15	4.76	---		
AC-FT	19250	37490	12120	11780	8890	13200	10290	11780	6880	---		

ST. LUCIA, LESSER ANTILLES

135022060572400 TROUMASSEE RIVER AT MAHAUT, ST. LUCIA, W.I.

LOCATION.--Lat. 13°50'22", long 60°57'24", at left downstream side of bridge on secondary road 5.2 mi (8.4 km) northwest of Micoud and 0.4 mi (0.6 km) southeast of Mahaut.

DRAINAGE AREA.--5.44 sq mi (14.1 sq km).

WATER-DISCHARGE RECORDS

PERIOD OF RECORD.--March 1984 to current year.

GAGE.--Water-stage recorder. Altitude of gage is about 400 ft. (122 m) above mean sea level, from topographic map.

REMARKS.--Records fair. Discharge for period of no gage-height record, March 11 to March 22, 1984, July 4 to July 24, 1984, and October 7 to December 3, 1984, were estimated based on the records from Buccament River at Pembroke, St. Vincent, W.I. for the same period of record and observer's gage height readings.

EXTREMES FOR WATER YEARS 1984-85.--Peak discharges above base of 500 cu ft/s (14.2 cu m/s) and maximum (*):

Date	Time	Discharge (cu ft/s)	Discharge (cu m/s)	Gage height (ft)	Gage height (m)	Date	Time	Discharge (cu ft/s)	Discharge (cu m/s)	Gage height (ft)	Gage height (m)
July 25, 1984	1545	1900	53.8	5.91	1.801	Sept. 14, 1984	1015	983	27.8	4.48	1.366
July 29	1345	581	16.4	3.64	1.109	Oct. 1	2400	752	21.3	4.03	1.228
Aug. 3	0900	994	28.2	4.50	1.372	Feb. 3	0515	710	20.1	3.94	1.201

Minimum discharges, 7.5 cu ft/s (0.212 cu m/s) June 1, 1984; 9.5 cu ft/s (0.269 cu m/s), Apr. 11, 12, June 24, 25, 29, 30, 1985.

1984 WY UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
135022060572400 TROUMASSEE RIVER AT MAHAUT, ST. LUCIA
LAT 135022 LONG 0605724 STATE 76 COUNTY 111 DRAINAGE AREA: 5.44

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1983 TO SEPTEMBER 1984
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1						---	10	9.4	8.6	153	34	11
2						---	9.8	8.7	9.0	129	26	10
3						---	9.4	9.4	11	112	163	10
4						---	9.0	14	11	69	36	15
5						---	9.0	12	9.3	30	25	22
6						---	8.9	8.9	8.8	25	22	14
7						12	8.8	8.6	8.8	23	21	12
8						11	8.9	14	9.9	17	20	11
9						11	9.3	18	11	15	20	13
10						21	10	15	9.5	15	18	33
11						14	9.0	9.9	9.7	24	21	16
12						12	8.7	11	11	17	21	12
13						11	8.6	8.9	10	14	18	26
14						12	8.5	8.4	9.5	19	15	186
15						14	8.4	12	9.7	13	15	51
16						48	8.4	19	11	17	15	36
17						30	8.9	11	10	11	13	20
18						17	9.4	9.1	14	10	13	15
19						16	8.7	9.0	11	10	13	13
20						14	9.6	8.6	11	16	14	13
21						16	8.9	9.9	11	18	12	13
22						13	8.7	14	11	12	12	19
23						15	9.3	9.9	16	11	11	16
24						13	9.6	8.4	31	13	13	113
25						16	8.9	8.8	22	347	17	19
26						14	8.7	9.4	14	142	14	12
27						30	8.4	9.4	12	32	13	13
28						30	8.2	8.4	11	49	12	12
29						16	8.3	11	11	119	11	18
30						12	11	9.8	23	38	11	11
31						11	---	9.3	---	24	11	---
TOTAL						---	271.3	333.2	365.8	1544	680	785
MEAN						---	9.04	10.7	12.2	49.8	21.9	26.2
MAX						---	11	19	31	347	163	186
MIN						---	8.2	8.4	8.6	10	11	10
CFSM						---	1.66	1.97	2.24	9.15	4.03	4.82
IN.						---	1.86	2.28	2.50	10.56	4.65	5.37
AC-FT						---	538	661	726	3060	1350	1560

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION

135022060572400 TROUMASSEE RIVER AT MAHAUT, ST. LUCIA
LAT 135022 LONG 0605724 STATE 76 COUNTY 111

DRAINAGE AREA: 5.44

PROVISIONAL DATA DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1984 TO SEPTEMBER 1985
MEAN VALUES

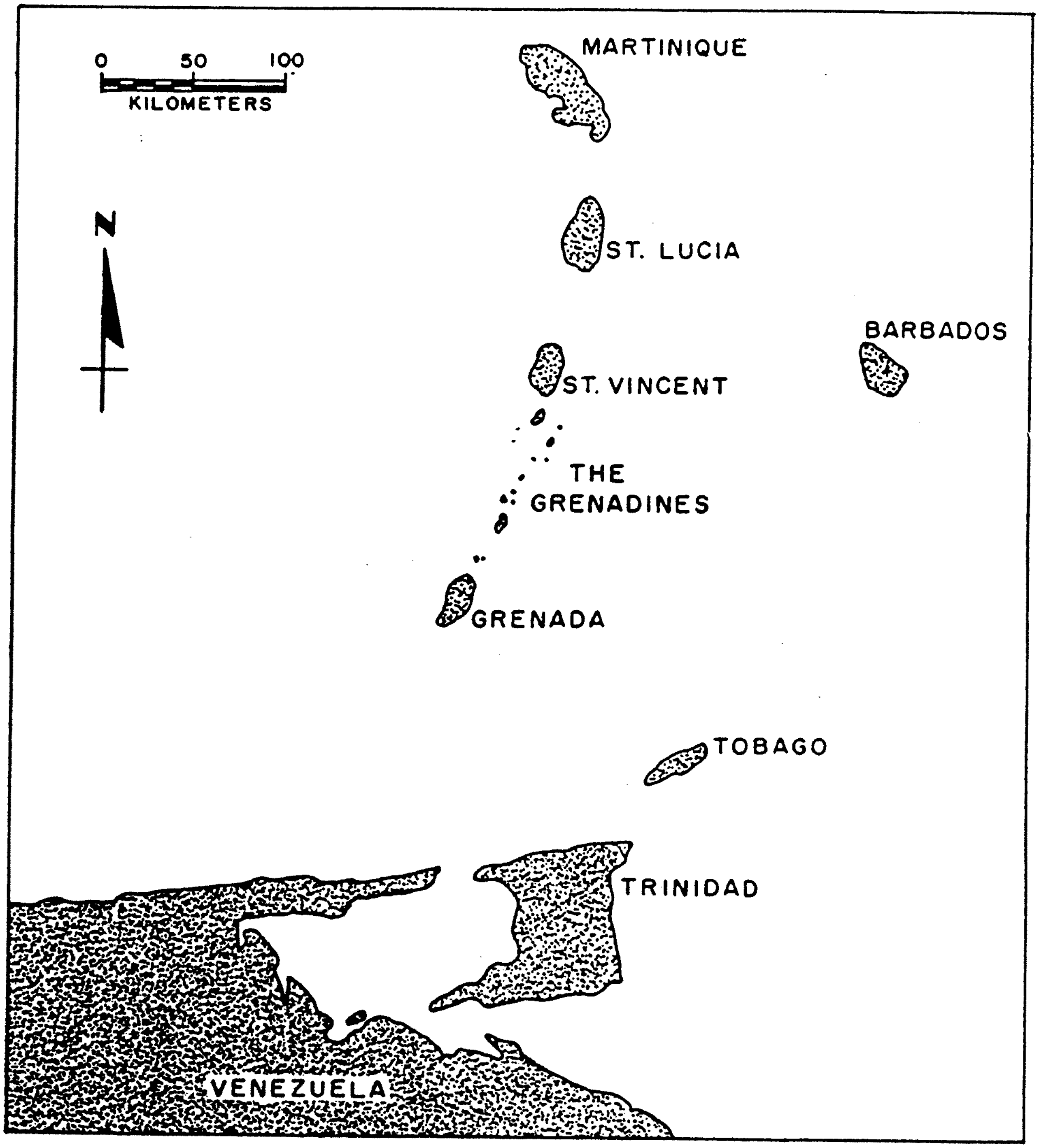
DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	44	26	36	17	91	20	24	29	12	17		
2	88	28	30	16	29	26	19	21	11	23		
3	14	32	25	16	193	38	13	17	11	23		
4	11	40	28	16	39	19	11	17	11	45		
5	10	60	25	23	27	19	11	15	11	105		
6	9.8	100	30	23	22	29	11	15	11	31		
7	59	132	28	18	19	19	9.9	14	11	18		
8	38	112	24	16	18	16	9.9	14	11	20		
9	30	215	22	15	17	15	12	35	12	---		
10	27	64	21	19	16	14	10	24	11	---		
11	31	60	25	16	15	17	9.8	27	15	---		
12	27	56	23	15	15	23	10	42	13	---		
13	24	58	20	14	14	15	16	25	12	---		
14	21	60	19	13	14	15	11	23	11	---		
15	20	62	18	27	16	13	26	38	11	---		
16	20	56	18	26	14	13	19	33	11	---		
17	25	50	17	19	17	15	17	21	11	---		
18	36	46	17	17	19	14	18	18	10	---		
19	32	41	17	16	24	13	19	17	20	---		
20	28	37	16	19	25	12	13	19	17	---		
21	25	34	16	15	19	13	24	28	12	---		
22	23	35	16	15	18	20	14	36	11	---		
23	22	40	16	15	22	15	11	35	10	---		
24	22	47	16	16	17	12	11	26	9.9	---		
25	23	45	29	17	16	11	10	20	15	---		
26	25	41	19	31	16	11	20	17	11	---		
27	27	42	28	22	17	11	23	16	9.9	---		
28	30	37	21	19	15	11	56	15	9.9	---		
29	35	33	18	21	---	11	30	15	9.9	---		
30	44	42	18	19	---	14	60	13	19	---		
31	56	---	19	54	---	23	---	12	---	---		
TOTAL	926.8	1731	675	605	784	517	548.6	697	360.6	---		
MEAN	29.9	57.7	21.8	19.5	28.0	16.7	18.3	22.5	12.0	---		
MAX	88	215	36	54	193	38	60	42	20	---		
MIN	9.8	26	16	13	14	11	9.8	12	9.9	---		
CFSM	5.50	10.6	4.01	3.58	5.15	3.07	3.36	4.14	2.21	---		
IN.	6.34	11.84	4.62	4.14	5.36	3.54	3.75	4.77	2.47	---		
AC-FT	1840	3430	1340	1200	1560	1030	1090	1380	715	---		

THE FOREST RESOURCES OF ST. VINCENT[1/]

Richard A. Birdsey, Peter L. Weaver, and Calvin F. Nicholls[2/]

1/ Publication also available in Spanish:
Weaver, P. L., Birdsey, R. A., Nicholls, C. F. Los recursos forestales de San Vicente.

2/ Richard A. Birdsey is Research Forester, Southern Forest Experiment Station, Forest Service - USDA, Starkville, MS. Peter L. Weaver is Research Forester, Southern Forest Experiment Station, Forest Service - USDA, Institute of Tropical Forestry, Rio Piedras, PR. Calvin F. Nicholls is Forest Supervisor, Ministry of Trade, Industry and Agriculture, St. Vincent and the Grenadines.


MARTINIQUE
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BARBADOS
ST. VINCENT
THE GRENADINES
GRENADA
TOBAGO
TRINIDAD
VENEZUELA

Birdsey, R. A.; Weaver, P.L.; Nicholls, C.F. The forest resources of St. Vincent. Res. pap. SO- . New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1984. p.

Presents the principal findings of a forest inventory of St. Vincent, West Indies, conducted in 1984. Data covers plantations and natural forests. Plantation species include *Pinus caribaea*, *Swietenia macrophylla*, and *Hibiscus elatus*. Natural forest vegetation covers 38 percent of the land surface and consists of primary rain forest, secondary forest, palm forest, dwarf forest, and dry forest.

Additional keywords: timber volume, forest area, tropical forest management, Caribbean forests, island ecosystems.

ACKNOWLEDGEMENTS

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INTRODUCTION

This study was part of a comprehensive investigation titled "Forests of the Caribbean islands: their role in development and their response to human and natural perturbations". The investigation had two major objectives. The first was to contribute to the assessment of natural resources (forests and watersheds) of selected Caribbean islands, by describing how these resources respond to environmental and human perturbations, and by developing management prescriptions for these resources. The second objective was to provide training for environmental officers from Caribbean islands.

This study responds to the first objective by providing a comprehensive overview of St. Vincent's forest resources. The second objective was supported during fieldwork when several St. Vincent Forest Service employees were trained in forest measurement techniques. This report is intended to assist St. Vincent Natural Resource Planners make rational and informed decisions regarding the development and use of forest lands.

Funding to conduct fieldwork in St. Vincent was provided by the United States Agency for International Development (U.S. AID). The work was carried out by personnel from the U.S. Forest Service, Southern Forest Experiment Station in cooperation with the St. Vincent Forestry Division.

HISTORICAL PERSPECTIVE

The Arawaks apparently occupied many of the Caribbean Islands as early as 100 B.C. (Bennett 1975). They were sedentary and derived their subsistence from the cultivation of maiz and root crops and through fishing. About 1000 A.D., the Carib Indians from South America began to invade north through the islands and by 1492 had reached the eastern end of Puerto Rico. This migration ceased with the arrival of the Europeans. By the 16th century, the

Amerindian population had been largely exterminated.

The British, French and Dutch invaders that arrived after St. Vincent's discovery were interested mainly in commercial agriculture and needed labor to operate the plantations. Slaves were imported from Africa and by the 18th century, plantation agriculture reached its apex under the British. Subsequent migrations and intermarriage have resulted in the following ethnic population groupings in St. Vincent (U.S. AID 1982): African Negro, 65%; mixed, 20%; East Indian, 5%; European White, 4%; Amerindian, 2%; others, 4%.

Population growth on the island since the mid-1800's has been classified into four major periods (Byrne 1969). From 1851 to 1881 and from 1911 to 1931, growth was moderate (Fig. 1). The intervening period had little population growth. Starting in the 1930's, and in particular after the war years, population growth accelerated. The 1979 census showed 111,170 inhabitants for St. Vincent and the Grenadines, or a population density of about 285 persons/km^2. About 7000 persons live in the Grenadines, more than half on the island of Bequia.

The following is a brief sketch of major social events that have influenced the island and its economy (Duncan 1970):

° 1498 -- St. Vincent was discovered by Columbus on the feast day of St. Vincent according to the Spanish calendar and was named in his honor.

° 1627 -- King Charles I of England assumed ownership of the island.

° Before 1750 -- Settlement occurred in the vicinity of Kingstown.

° 1763 -- Constitution bestowed by King George III; probably the day on which Kingstown was named.

° 1765 -- Colonists rushed to the island.

-- Botanical garden established in Kingstown for introduction of tropical species from other regions.

° 1793 -- Captain Bligh introduced breadfruit to the botanical garden from which it spread to other areas in the neo-tropics.

° 1822 -- Trade began with the United States.

° 1850 -- A decrease in the market price of sugar lead to widespread planting of arrowroot on the island.

° 1930's -- Population growth began to accelerate.

° 1953-54 -- Government warehouse in Kingstown was built. Bananas became the leading export crop.

° 1979 -- St. Vincent and the Grenadines became an independent state within the British Commonwealth after 10 years as an Associated State of the United Kingdom (U.S. AID 1982).

The botanical garden outside Kingstown, the oldest in the new world, deserves mention. It was established for "the cultivation and improvement of many plants now growing in the wild and the importation of others from similar climates" (Howard 1954). Alex Alexander was appointed director in 1785 and under his direction the garden reached its peak of maintenance and inventory including 1170 species of commercial and medicinal plants, esculents, fruits, valuable woods, and ornamentals (Howard and Howard 1983). Among the most renowned introductions were nutmeg, and breadfruit trees from Captain Bligh's voyage after the Bounty mutiny. In the early 1900's agricultural experimentation was carried out in the garden but by 1920, these functions had been transferred to nearby Camden Park. Currently, the botanical garden is a place of beauty with many interesting plants and a rich tradition in economic botany of the West Indies.

THE FOREST ENVIRONMENT

St. Vincent is located at 13° 15' N latitude and 61° 12' W longitude in the Caribbean Sea. The island measures about 29 km long and 18 km wide at its maximum dimensions and encompasses about 345 km^2. The St. Vincent Grenadines, politically part of St. Vincent, consist of 7 main islands stretching about 60 km to the south toward Grenada and occupy a total of 44 km^2. The largest and most proximate to St. Vincent is Bequia which covers 18 km^2.

St. Vincent lies about 175 km west of Barbados and about 300 km north of the Paria Peninsula of Venezuela. The interior of the island is steep and rugged and has not yet been traversed by a road. This land remains undisturbed and contrasts with the coastal zone and lower elevations where the island's population resides.

The interrelations of geology, physiography, climate and soils influence the structure and composition of the forests. Recurrent hurricanes and volcanic eruptions have had a considerable impact on the island's vegetation, agriculture, and population.

Geology and Physiography

St. Vincent is entirely volcanic in origin (Macpherson 1977). Its volcanoes have developed on a subsiding narrow submarine ridge about 1500 m below the current sea level (Hardy 1939). The first volcanic eruptions apparently occurred during the late Miocene and have continued intermittently, producing a series of volcanic piles, the oldest of which are in the southern part of the island.

Soufriere in the north rises to 1220 m within 3 km of the coast (Fig. 2). A deep trough across the island separates the solitary cone from the remaining mountains to the south. The southern range extends for about 15 km with highpoints at Richmond peak, 1075 m, Mount Bisbane at 930 m near the middle of the island, and Grand Bonhomme at 960 m in the south central part of the island. The main ridge that runs down the central axis of the island never dips below 600 m in elevation. Andesitic and basaltic agglomerates are common (Earle 1928). All rocks are Pleistocene to recent in origin (Watson et al 1958).

Soufriere which dominates the northern part of the island erupted in 1718, 1812, 1902 (Howard 1962), and again in 1979 (Rowly 1979). It has apparently been erupting violently about once every 100 years for the last millennium. Historic eruptions have been characterized by nuees ardentes, or incandescent avalanches that carbonize material in the absence of oxygen as they rush downslope. These eruptions have been accompanied by ash fall and mudflows. The crater lake inside the volcano disappeared after the 1979 eruption. Today deep, largely unvegetated gullies radiate from the summit.

During the Pleistocene more than half million years ago, St. Vincent was subject to marine submergence and intermittent uplift creating a series of flat-topped terraces of which seven are evident in the southeast (Watson et. al. 1958). Subaerial erosion has modified the terraces producing a rolling landscape.

Towards the south, the land becomes progressively older and more mature with deeper and wider valleys and lower ridges. The central mountains are characterized by sharp ridges and deep, steep-sided valleys. Numerous lateral ridges emanate from the central mountains. In the west, these are steep and separated by deep, narrow gorges. To the east, they slope more gently with wider, flatter valleys that form coastal plains of fair extent in a couple areas (Beard 1949).

Nearly 60 percent of the land surface lies below the 300 m contour and slightly more than one percent above 900 m. About 27 percent of the land lies between 300 to 600 m, and 13 percent between 600 and 900 m.

Climate

Daily and annual temperature fluctuations are minor because of the influence of the surrounding ocean. The 10-year record at the Botanical Garden in Kingstown showed a mean annual temperature of 26.7°C with a maximum of 31°C (Wright 1929). The annual range of mean monthly temperatures was only about 2°C while the diurnal range of temperature was about 5°C (Walker 1937).

The island is influenced by tradewinds, in particular during the winter months. The annual migration of the equatorial convectional rains, however, provides a well-defined June through November rainfall maxima (Fig. 3). Mean annual rainfall for the Botanical Garden determined from a 33-year record between 1894 and 1927 was 2615 mm and ranged between 2030 and 3500 mm (Wright 1929). The comparatively dry season from January to early May tends to be accentuated by soil porosity, steep slopes, and exposure to wind and sun (Beard 1944a).

St. Vincent lies just within the hurricane belt and averages one hurricane about every 25 years. The earliest on record occurred in 1780 and did great damage (Beard 1945). There was a storm of lesser intensity in 1819, severe ones in 1830 and 1886, a slight one in 1897, and a severe storm in 1898. A moderage hurricane struck the island in 1921. On September 8, 1967 and on August 8, 1980, hurricanes Beulah and Allen traversed the island. During the latter two storms, only 2 persons were killed, but more than 20,000 were affected by storm damage.

The climate in the interior is cooler and wetter but the lack of climatic stations means that estimates of rainfall are somewhat speculative. Available climatic maps (Macpherson 1977; Caribbean Conservation Association et. al. 1980) show a gradual increase in rainfall from about 1800 mm/yr in coastal areas to over 3800 mm/yr in most of the central mountains with possible rainfalls in excess of 6000 mm/yr in the area surrounding the summits. Using the isohetal map (Caribbean Conservation Association et. al. 1980) and assuming an average rainfall of 1800 mm/yr for the coastal areas, 6600 mm/yr for the summits, and the mean between the isohets for the remaining areas, St. Vincent receives an average of about 3000 mm/yr over the entire island.

Examination of recent rainfall records shows several gaps in data collection which bias the data toward underestimates of total rainfall and make comparisons among stations tenuous. Similar observations were made at an earlier date (Walker 1937).

Soils

The soils of St. Vincent are derived mainly from loose, fragmental volcanic ejecta such as boulders, stones, cinders, sand, and ash (Hardy 1939). There are 3 major soil groups:

° Coastal plain and valley alluvial soils -- These soils occupy flat land near the coast, valley floors, and mouths of small estuaries. The material from which they are derived consists of loose, black, volcanic sand transported from higher elevations. They are fertile and subject to little erosion.

° Recent volcanic ash soil -- These are incipient soils recently derived from fragmental ejecta (in Hardy's case, from the 1902 and earlier eruptions).

° Yellow earth soil -- These soils are found on the rest of the island and display varying degrees of maturity and considerable variation in physical features and natural history.

In general, island soils have been described as immature with a high content of unaltered minerals, markedly uniform in vertical profile and containing low contents of weathered products. Furthermore, they are neutral to slightly acidic in reaction, contain medium-high contents of organic matter and are highly permeable to water. The rate of solution of mineral components is low, and the contents of available potash and phosphate are low. They have a low saturation capacity, low content of exchangeable bases, and a high degree of base saturation (Hardy et. al. 1934). Although such soils would not be expected to erode rapidly because of their high permeability to water, sheet, rill, and gully erosion and land slip are observable today in different parts of the island.

AGRICULTURE

St. Vincent's economy has traditionally depended upon export crops. During the 1700's sea island cotton was grown extensively on the island but at the beginning of the 1800's plantation-grown sugar cane became the foremost crop. After 1850, following emancipation, sugar production declined. Concurrent with its decline, the cultivation of arrowroot as a cash crop was started by many small farmers. At the turn of the century, arrowroot and cotton continued as the leading export crop of the island.

Before 1897, most of the agricultural land belonged to large estates. In that year, a Royal Commission recommended that the government purchase large estates and fragment them for distribution among small farmers (Beard 1944a). Land tenure statistics as of 1944 for 177 km^2 of 'alienated' land were as follows: under 2 ha, 15%; 2.1 to 4 ha, 8%; 4.1 to 20 ha, 8%; 20.1 to 40 ha, 3%; 40.1 to 400 ha, 58%; and greater than 400 ha, 8%.

Current statistics from the Ministry of Trade, Industry and Agriculture concerning the production of agricultural crops on the island were summarized for 1981 (Fig. 4). About 4000 ha or 36 percent of the area for which statistics were available were planted in starchy root crops. Bananas with about 2710 ha (24 percent of the area), coconuts with 2340 ha (22 percent), sugar with 650 ha (6 percent) and arrowroot with 450 (4 percent) were the next most common crops.

The total value of crop production for 1981 was $23,408,580 (U.S. dollars) for the 22 crops evaluated. Bananas were the most important with about 48 percent of the total. Starchy root crops with about 12 percent, coconuts with over 11 percent, mangoes with about 6 percent, and arrowroot and ginger with about 5 percent each were the next most valuable crops.

Dietary staples include rice, sweet potatoes, yams and cassava which are accompanied by fish, pulses, other vegetables and fruits, cheese and other milk products, and meats. Bananas, the most important export crop, and arrowroot, the second most important export crop, are grown on small farms averaging between 0.5 and 1.0 ha in size. St. Vincent arrowroot produces a high quality starch that is used for the manufacture of computer paper and in home and pharmaceutical products. Coconuts are grown principally on large farms while vegetable and fruit production takes place on small properties for home use and sale. Food crops include sweet potatoes, tannias, dasheen, eddoes, carrots, yams, pumpkins and mangoes (U.S. AID 1982). The majority of agricultural production is aimed at the export market in the United Kingdom, other Caribbean islands, and North America.

WATER RESOURCES

St. Vincent is a small island with a high population density in the South. A continuous water supply is a basic need which must be met with the limited water resources available locally. Water supply problems that have occurred on nearby islands indicate that St. Vincent's water resources should be carefully assessed.

The rivers of St. Vincent are short and straight. In the mountains, their steep courses run through deep, narrow valleys. At lower elevations, they broaden into small delta-shaped alluvial flats. The largest river on the island is the Colonarie and the second largest is the Wallabou.

If the estimate of 3,000 mm/yr of rainfall for the entire island is reasonably accurate, then St. Vincent receives 1.035×10^9 m^3 (about 838,500 acre feet) of water on its surface each year. No estimates are available for runoff, evapotranspiration or ground water storage.

Twenty major water supply sources and hydropower sites are located in several watersheds circumscribing the central mountains (Fig. 2 and Table 1). Combined, these supply sources have a dry intake capacity of 4.53×10^6 gal./day and a wet intake capacity of 7.77×10^6 gal./day.

THE NATURAL VEGETATION

The Flora of St. Vincent lists 1,150 species with about 250 trees and shrubs (Anonymous 1893). Subsequently, much botanical work was done in the forests of St. Vincent and elsewhere in the Caribbean (Beard 1942, 1944a-d, 1949; Stehle 1945) with principal interest in the trees and forests of the region. Later, the vegetation of the Grenadines was studied, including the islands belonging to St. Vincent (Howard 1952). Dendrological descriptions of many of the tree species found in St. Vincent, their areas of occurrence elsewhere in the hemisphere, and their potential uses have been documented (Little and Wadsworth 1964; Little, Woodbury and Wadsworth 1974). Many have been classified as valuable native and plantation sawtimbers (Longwood 1961, 1962; Fraser 1957). The following summary of the natural vegetation is based on Beard's (1949) classification which is still largely applicable (Fig. 5).

Climax communities

Rain forest --The rain forest occupies small areas between 350 and 500 m elevation, principally in the headwaters of the Colonarie, Cumberland and Buccament Valleys. The forest averages about 30 m tall, is closed and dense, and has two strata of trees. It is somewhat patchy in occurrence due to storm damage and topography. Windward and leeward forests are similar in composition with the exception of Prestoea montana which forms about 35 percent of the stems to the windward and is virtually absent to the leeward. The canopy dominants are Dacryodes excelsa, Lauraceae spp., Meliosma herbertii, Micropholis chrysophylloides, and Sloanea caribaea which constitute over 50 percent of the stems excluding P. montana.

Elfin woodland -- The elfin woodland occupies exposed summits above 500 m on both sides of the central mountains. The forest is short, 4 m or less in height, composed of gnarled trees that are covered with moss and epiphytes. The principal tree species include Charianthus coccineus, Didymopanax attenuatum, Freziera hirsuta, P. montana, Inga laurina, Weinmannia pinnata and species of Ficus and Clusia.

Littoral woodland -- The littoral woodland occurs in limited areas adjacent to the sea. The forest varies in height depending upon exposure but usually does not exceed 8 m. Coccoloba uvifera, Rheedia and Tabebuia pallida are common dominants.

Mangrove -- There is a very small area of mangrove on the south coast which contains Rhizophora mangle and Avicennia germans.

Secondary communities

Palm brake -- The palm brake occupies exposed areas above 500 m on both sides of the mountains. About 70 percent of the stems are palms that reach 12 m tall in some places. The remaining species are second-growth pioneers or occasional trees from the rain forest.

Secondary rain forest -- Secondary rain forest generally occurs above areas of permanent cultivation and below the rain forest. Several areas are partially cultivated by farmers and contain a large component of secondary species including *Chimarrhis cymosa*, *Sapium caribeum*, *Inga ingoides*, *Cecropia peltata*, *Freziera hirsuta*, *Ochroma pyramidale*, *Cordia sulcata* and species of *Lauraceae*. More advanced succession contains a greater number of rain forest species.

Soufriere -- With recurrent eruption of Soufriere, the area surrounding the mountain is in a constant state of disturbance ranging from exposed soil immediately after eruption to fairly advanced stages of succession after many years without vulcanism. Because of the elevational gradient, many plant communities would become established without disturbance ranging from rain forest at the lowest elevations through 'paramo' to 'tundra' at the summit. Succession follows a general displacement of communities upwards as it progresses. This succession has been described by several authors (Anderson 1908; Beard 1945, 1949, 1976; Howard 1962; Sands 1912).

Dry scrub woodlands -- Dry scrub woodlands occupy uncultivable land on precipitous, rocky slopes where luxuriant forest never existed. It has been heavily felled for timber and fuelwood. Dominant tree species include *Bursera simaruba*, *Pisonia fragrans* and *Acrocomia sp.*

King's Hill reserve in the southeastern part of the island is a unique exception. Largely undisturbed since its creation, forest reaching 20 m in some areas has developed. In addition to the hardwoods mentioned above, *Tabebuia pallida*, *Swietenia mahagoni*, *Hymenea courbaril*, *Pouteria multiflora*, *Inga laurina*, *Mastichodendron foetidissimum*, *Brosimum alicastrum* and *Lauraceae spp.* are found as dominants.

FOREST LEGISLATION AND LAND OWNERSHIP

The principal ordinances concerning forests on St. Vincent are the following (Beard 1944a):

- The King's Hill Enclosure Ordinance 82 of 1926 (No. 5 of 1791) - reserves about 22 ha of woodlands on King's Hill for "the purpose of attracting the clouds and rain ... for the benefit and advantage of the owners and possessors of lands in the neighborhood thereof." Penalties are prescribed for cutting timber and squatting.
- The Charcoal Ordinance 98 of 1926 (No. 5 of 1906) - prescribes penalties for unlawful burning of charcoal and is used to control charcoal burning on Crown lands.
- Crown Land Ordinance 77 of 1926 (No. 3 of 1906) - deals mainly with surveys and squatting on Crown lands and also contains provisions for a Superintendent of Crown lands, a means of making regulations for management, sale, lease and prevention of squatting on the lands, and prescribes penalties for squatting and unauthorized cutting.
- Proclamation of August 22, 1912 - reserved all Crown lands above 1000 feet elevation to protect them from any act that would be prejudicial to forest conservation. This area has been estimated at 168 km^2 or slightly less than half the island.

At the time Beard drafted his statements, it was felt that legal protection of the forests was inadequate. Since that time, cutting and clearing in the forest has continued, mainly for subsistence agriculture. Steep slopes, heavy rainfall and lack of access roads, however, have restricted the invasion of crown lands. Lands classified as 'alienated' or private total 177 km^2 or slightly more than half the island.

FOREST PLANTATION SURVEY

Plantation Description

Of the 50.6 ha of plantation for which we could find records, *Hibiscus elatus* accounted for a little over 70 percent of the total area (Fig. 6). *Pinus caribaea* and *Swietenia macrophylla* accounted for another 18 percent of the plantations. About a third of the plantations were established in 1968-69 and about 40 percent in 1982 with a steady rate of 2 to 4 ha planted in most intervening years. The increase in activity starting in 1981 was possible due mainly to financial assistance from U.S. AID under its basic Human Needs Program, administered by the Caribbean Development Bank. At the First Workshop of Caribbean Foresters, *Hibiscus* was reported to occupy 75 ha on St. Vincent, *Pinus* 30 ha, and *Swietenia* 18 ha (Nicholls 1982).

Plantation measurements were made at 19 different sites (Table 2). The methods used to determine standing volumes and growth rates were presented at the Second Workshop of Caribbean Foresters (Weaver and Valenta 1984). Stand volume varied considerably by species, site, age and previous silviculture and ranged from 5.6 m^3/ha for 9-year old *Cordia* at Government House to a surprising 575 m^3/ha for 21-year old *Pinus* at Hermitage (Table 3). In Young Man's Valley, where all the species were planted in 1969 and thinned in 1976, *Pinus* attained the greatest mean diameters, mean heights and total volume. At Hermitage, where plantings were done in 1962-63 and thinnings in 1976, again *Pinus* showed the largest mean dimensions and volume. The latter plantation was located on a terrace and appeared to have been well tended. Both of these factors contributed to the fine growth. The *Swietenia* plantations at Hermitage differed in mean diameters, mean heights and total volumes with the thinned stand showing better growth than the unthinned stand.

At Vermont, Calophyllum, Hibiscus, and Pinus were established between 1971 and 1973 and had never been thinned. Pinus again had the largest dimensions and volume. Hibiscus and Calophyllum had nearly equal diameters and volume while the height of Hibiscus averaged a couple of meters taller.

At Montreal, the plantations of Hibiscus and Pinus were established in 1966 and 1967. The Hibiscus was thinned in 1974. One of the Pinus plantations was thinned in 1979 and another in 1982 while the last plantation remained unthinned. The Hibiscus growing on the slope had larger dimensions and volume than that on the bottomland. The Pinus thinned in 1979 had greater mean diameter and mean height but less volume than the unthinned stand, both of which were on gentle midslopes. The remaining Pinus stand, thinned in 1982, was situated in an area exposed to wind and had less height and volume than the other stands.

In secondary forest at Camden Park, Swietenia mahagoni constituted 75 percent of the stems. Its mean diameter and height was considerably less than that for Tabebuia pallida. Basal area for both species combined was 17.8 m^2/ha and the total volume 134.8 m^3/ha.

Diameter growth rates ranged between 0.62 and 2.06 cm/yr, height growth between 0.66 and 1.80 m/yr, and volume growth between 0.42 and 28.76 m^3/ha/yr for all species and sites combined (Table 3). In general, the best growth was attained by Pinus and the poorest by Cordia. Hibiscus showed the least variation in diameter, height and volume growth regardless of age, site or silvicultural treatment. On the other hand, Swietenia macropyhlla appeared to have better diameter and volume growth when thinned.

Although the scope of this survey of forest plantations was limited, some preliminary observations are possible:

° *Swietenia macrophylla* showed poor form on most sites, with low branching and excessive crown development. Most of this poor form is probably attributable to shoot borer (*Hypsipyla grandella*) infestation. Lack of a 16 foot (5 m) clear stem will seriously reduce the stand value and utility at maturity.

° About 70 percent of the stands have high basal areas in excess of 25 m^2/ha. Although *Pinus* and *Hibiscus* are narrow-crowned species, and able to tolerate high stem densities for several years, continued development without thinning will result in slower growth on the rotation trees and high stand mortality. Timber production on existing stands could be improved with thinning, but without studies using different spacings and thinning regimes on several sites, it is difficult to prescribe the best management practices for a complete rotation. Unthinned *Swietenia* at Hermitage has already begun to slow in diameter growth because of stand density.

° Incomplete records make assessment of growth and development, and the extrapolation volumes on an areal basis, extremely difficult. Accurate data on plantation establishment dates, original spacings, dates and types of thinnings, and recurrent measurement of select plots for growth analyses are needed.

Management Recommendations

Except for Government House, the forest plantations are concentrated high in watersheds where clearing and cultivation of subsistence crops is underway. Most of the land is government property that has been "reclaimed" through the establishment of plantations. Efforts to increase plantations in these areas should continue both for the provision of lumber and to deter further advance of cultivation into the interior of the island.

Many of the plantations are very dense. The close spacing that is traditionally used throughout the island offers a chance for selection of better stems after 4 or 5 years. Thinning at this time would enhance the development of better trees and maintain good growth over a longer period of time. Other spacings and thinning regimes should be studied. Perhaps the 1981-82 plantations established with U.S. AID assistance could provide a starting point for silvicultural research in cooperation with outside institutions.

An alternative method for the establishment of Swietenia macrophylla should be investigated. The tree's high value and utility assure a ready market. Shoot borer infestation may be diminished by line planting widely spaced Swietenia interspersed with other fast growing timber species. In subsequent thinnings, the better formed Swietenia could be favored.

1984 FOREST INVENTORY

The St. Vincent forest inventory was designed to provide two kinds of information: estimates of forest area for various forest classes, and statistics describing the composition of "timberland" or forests with some commercial potential. The presentation of data in commercial terms should not be construed as a recommendation for exploitation or management of natural forests. Rather, the information is intended to be used as background material for planning and research concerning forest resources on the island. Natural forests in St. Vincent have important functions such as watershed and wildlife habitat protection, and provision of tourism and recreation opportunities. Any decisions which affect these unique forests must be carefully made.

The inventory was designed as a reconnaisance survey to provide island-wide forest resource information. The data were derived from photointerpretation and field observations at sample locations; the data represent "average" conditions within forest communities on the island. Since the forests are quite heterogeneous due to varying levels of human impact and diverse site conditions, the information cannot be used to describe conditions or develop management plans for specific sites.

Methods

The data on forest areas, timber volume, and species composition were obtained by a sampling method involving a land cover classification on aerial photographs and on-the-ground measurements. A dot count method was used to obtain an initial estimate of area by land cover class. This estimate was adjusted on the basis of a ground check of actual land cover at each of the sample locations.

Ground sample locations were selected on a base map at the intersections of a grid of lines spaced 2 kilometers apart. Each sample location was visited to determine cover class. The center of each forest location classified as timberland was accurately located by running a computed azimuth and distance from an identified starting point. Detailed field measurements were taken at all accessible timberland locations.

A cluster of 3 permanent sample plots was established at each timberland location. Sample plots were located 25 meters apart. At each sample plot, trees larger than 12.5 centimeters in diameter at breast height (dbh) were tallied on a variable-radius plot, with each tree representing 2.5 square meters of basal area per hectare. Trees less than 12.5 centimeters dbh were tallied on a fixed radius plot of approximately 40 square meters around the first sample plot, and 15 square meters around the other two sample plots.

This sample plot design was determined to be efficient for similar forest conditions in Puerto Rico (Birdsey 1984).

Each sample location was classified by numerous site characteristics. Each sample tree 12.5 centimeters and larger was measured and assessed to determine timber volume and quality. Species was accurately determined for all sample trees. Detailed field measurements were assembled into a handbook (USDA Forest Service 1984). All definitions and inventory standards are listed in the appendix to this report, along with a species list and some useful conversion factors.

All field data were recorded on tally sheets, transferred to the computer, and edited for errors prior to compilation. Errors were kept to a minimum by careful training, diligent field work, and a detailed edit procedure which checks all items for consistency and reasonableness.

All field work was done between January and April, 1984. Photointerpretation for area estimation was done prior to field work using 1:25,000 scale panchromatic photography acquired during January, 1981.

A total of 3,168 photo samples were classified, and 88 ground locations were checked. Detailed forest measurements were taken at 57 sample plots clustered at 19 sample locations.

Forest Classification

The forest classification corresponds to the natural vegetation communities described by Beard (1949). These communities can be recognized with reasonable accuracy on the aerial photographs and verified on the ground. Timberland is composed of those forest classes occupying sites which can be used for timber production. Timberland classes in St. Vincent include the rain forest climax and secondary communities, here described as young secondary, secondary, and primary. Plantations are included in timberland since they are located on sites which would otherwise support one of the rain forest classes.

Other forest land includes forest classes occupying sites that are sensitive to disturbance and would generally not be productive for timber crops. This class includes the palm forest and dwarf (elfin) forest which are found on exposed sites above 500 meters, and the dry scrub forest which is found on very steep, rocky slopes or adjacent to the sea. Maintenance of forest cover on these sites is critical to protect water catchments from severe erosion.

Forest Area

Forests cover 13,000 hectares or 38 percent of the land surface of St. Vincent (Table 4). Secondary or successional forests account for more than half of all forest land. Nearly 5 percent of the land area is composed of mature, mostly undisturbed primary rain forest. This and the undisturbed palm and dwarf forests are among the largest remaining contiguous areas of relatively unaltered ecosystems in the Lesser Antilles (Putney 1982). Located in the rugged central mountains, the primary rain forest is the home of several endangered species, including the St. Vincent parrot *Amazona guildingii*. The parrot habitat is protected as a sanctuary, and these protected lands include all of the primary rain forest.

Forest area has declined slightly over the past 10 years, based on an FAO estimate of 41.2 percent total forest in 1974 (Food and Agricultural Organization of the United Nations 1975). The change is due to the 1979 eruption of Soufriere which accounts for much of the 2,750 hectares of nonstocked or bare land.

The distribution of forest land in St. Vincent is largely the result of settlement patterns. Most land suitable for agriculture is found at elevations below 1,000 feet and has been cultivated for many years. Forest cover is nearly absent below 1,000 feet on the Eastern or windward side (Table 5). The Western or leeward side is much more rugged, with the area below 1,000 feet including many pockets of forest on land which is too steep to cultivate. The Northwest region is the most rugged and contains the highest proportion of forest.

All land above 1,000 feet has been reserved by law for many years to protect the forest, although many parcels are leased for nonforest use. Few roads penetrate the interior, and despite encroachment problems, the remote area has retained a high proportion of forest cover. The main exception occurs in the Southeast where the proportion of forest land above 1,000 feet is only 32 percent. Here a fairly dense road network penetrates well into the reserved land. This region would likely be the first to experience water supply problems during a drought due to the high population density, sparse forest cover, and location of 6 water intakes.

Timberland Characteristics

Primary rain forests are located at the highest average elevation and farthest average distance from roads of the three major timberland classes (Table 6). Young secondary forests are more accessible and tend to be associated with recent agricultural activity. The average distance to water for all timberland is less than 100 meters.

Both young secondary and secondary forests have similar basal areas, but the young secondary forests average nearly twice the number of stems (Table 7). The younger forests have a smaller average diameter and canopy height.

These statistics suggest that, in the successional process, the disturbed site is quickly occupied by a large number of small stems which compete vigorously until a secondary stand is well-established. The secondary forest then matures over a long period, accumulating biomass to reach a potential basal area of more than 30 square meters per hectare.

At some point during the maturation process, the number of small stems again begins to increase as shade tolerant understory species and saplings of canopy species become established. The climax forest develops the appearance of two distinct strata, with the upper canopy height averaging more than 25 meters above the ground. The basal area of saplings is significantly higher than that of poletimber, with large sawtimber-size trees clearly dominating the available growing space (Fig. 7).

Wood volume accumulates steadily over time. Most of the volume in young secondary forests is found in large residual trees which have outlasted surrounding disturbances. Young secondary forests average two large trees per hectare in the 75 centimeter dbh and larger classes, and no trees in the 50 to 70 centimeter dbh classes (Table 8). Secondary forests have 18 and mature forests 43 trees per hectare greater than 50 centimeter dbh.

Much of the apparent variability in these statistics is due to the intermingling of the 3 timberland classes. Steep slopes, unstable soils, high rainfall, periodic storms and volcanic eruptions create a very dynamic forest. Sample plots established randomly under these conditions capture a great deal of this natural diversity.

Species Composition

Species composition varies considerably between the 3 timberland classes (Tables 9, 10, 11). Although the classes represent 3 stages of a successional process, an orderly succession of species is not immediately apparent. Inventory sample plots were scattered about the island in different forest stands, so the data does not represent a series of observations of a changing forest, but rather a snapshot of current forests in different stages of development. Tropical species are seldom distributed uniformly over an area, and St. Vincent is no exception. Individual species tend to have a clustered distribution which enhances the stand and site variability associated with diverse stand origins and physiography, and varying disturbance levels.

Many of the species listed in the tables were sampled at only one location. It was not possible to install enough samples to intensively study individual species. Generally, the data on larger trees (poletimber and sawtimber) sampled with a prism are more accurate than the data on saplings. It follows that the species data for young secondary forests are least reliable, and data for the primary forest are most reliable. In the following discussion only species which seem to have been reasonably well sampled are mentioned.

Young secondary forests are composed of pioneer saplings and poletimber such as Inga vera and Cecropia peltata. Several species are common as saplings but absent from larger size classes. Scattered large trees are remnants of previous forests, including Dacryodes excelsa, Chimarrhis cymosa, and Licania ternatensis.

Secondary forests contain many of the same species, with pioneers reaching maturity and the longer-lived species beginning to form a canopy (Table 10). Inga vera is clearly the dominant species, accounting for 16 percent of the basal area and 29 percent of all sawtimber trees. Prestoea montana and Cecropia have persisted and many have reached maturity. Chimarrhis and Ficus citrifolia are common with diameters between 50 and 70 cm. Again, some species are present only as large residual trees from prior forest stands or old fields.

The primary forest has quite a different composition than younger successional forests. Short-lived pioneers and secondary species have been replaced or outgrown by overstory giants of many different species, and some new understory species which are adapted to the moist, shady environment beneath the canopy have appeared.

Dacryodes, Licania, Ormosia monosperma, and Sloanea massoni together account for 40 percent of the basal area and 33 percent of all sawtimber trees. Several species were encountered only as large sawtimber specimens with no evidence of reproduction under the canopy or in successional forest classes. Absent from the mature forest were several common successional species: Inga vera, Prestoea, Cecropia, Ficus, and Chimarrhis.

For all classes of timberland combined, Inga vera comprises the most basal area, followed by Licania, Dacryodes, and Cecropia. The largest dbh recorded was a Sloanea at 100 centimeters. The tallest tree was another Sloanea at 48 meters.

Timber Volume

Timber volume is the volume inside the bark of all sound wood, including bole and branch defects such as crook or large knots, of all tree sections with a minimum diameter of 10 centimeters and a minimum length of 1 meter. This represents the wood volume removed from the forest for all forest products other than fuelwood. Growing-stock volume excludes the cull or rough sections and all of the wood in trees classified as rough or rotten due to excessive incidence of these defects. This is the wood volume that the commercial logger would remove from the forest for use as pulpwood, sawtimber, or veneer bolts. Sawtimber volume is the net volume of sawn wood in all trees larger than 27.5 centimeters dbh that contain a minimum size sawlog of 22.5 centimeters diameter outside bark and 3.5 meters in length. This is the volume that would be produced after the good quality bole and large branch sections were hauled to the sawmill and cut into lumber.

Timber volume in the young secondary forest averages 52.7 cubic meters per hectare. The average rises to 98.6 cubic meters in secondary forests and 251.3 cubic meters in the mature forest. The majority of the volume is found in larger trees in the older forest classes, although the volume in all size classes also tends to increase (Fig. 8). Of most interest to the prospective logger is the volume in large sawtimber trees (larger than 47.5 centimeters). This category shows the most change among forest classes.

Most of the useable volume in young secondary forests occurs in the occasional large residual trees. This is best indicated by the sawtimber volume total which averages 7.2 cubic meters per hectare, mostly in *Dacryodes* and *Licania* (Table 12). *Inga vera* and *Cecropia* account for more timber volume, but this is in smaller sawtimber and poletimber. *Inga vera* has some utilization potential for utility or construction grade products.

Inga vera is also the principal timber species in secondary forests (Table 13). Sawtimber volume for all species averages 13.7 cubic meters per hectare, with 4 species accounting for 72 percent of the total. Of these 4, *Dacryodes* and *Chimarrhis* are present in large sawtimber sizes and would be the preferred harvest species.

Secondary forests are reasonably well stocked with timber, with some individual stands carrying as much as 44 cubic meters per hectare of sawtimber. Factors that might limit the availability of this timber by making it uneconomical or impractical to harvest include accessibility, terrain roughness and slope, and the ecological values of the forest. Much of the secondary forest is located in very rugged terrain which is not inhabited and does not contain roads or even good trails. The forests are probably the result of natural rather than human disturbance. Physical difficulties limit the opportunities for log extraction. Of additional concern is the ecological value of these secondary forests, and the role they may play as seed sources and habitats for many plant and animal species. The parcels are often located adjacent to or within mature timber stands as a part of a single, dynamic forest ecosystem.

The mature, undisturbed forest carries the high volumes usually reported for the tropical moist forest (Table 14). Many different species are represented by large, mature individuals which contain as much as 20 cubic meters of timber. Sawtimber volume averages 65 cubic meters per hectare, with high quality timber accounting for 44 percent of the total. Dacryodes, Ormosia, Actinostemen caribeus, and Talauma dodecaceptala together comprise 59 percent of all sawtimber.

The dense timber stands are unlikely to be harvested soon due to the extremely rugged terrain and lack of roads or easy access. The primary forest may be the most valuable natural resource of the island because of its limited distribution in the Antilles, and the uniqueness of the vegetation on each island. Besides helping to maintain the island ecosystem and sustain water supplies in the water catchments, the natural forests have the potential to attract tourists and provide habitat for interesting and endangered wildlife species. Since the mature tropical forest may take hundreds of years to fully regenerate, this resource should be managed with the greatest care.

The majority of the timber in young secondary and secondary forests is contained in rough cull trees (Table 15). Successional species have a tendency to become crooked and limby because of the amount of growing space available in early years. Some of the large, residual trees on abandoned agricultural land were open-grown as well.

In contrast, two-thirds of the timber in the primary forest is found in growing-stock trees. These trees have survived competition by growing tall and straight in early years and shedding lower branches. Because of the size of these trees, 20 percent of the timber is contained in branches, forks, and large sections of the bole above the sawlog.

For all timberland classes combined, *Dacryodes* has the highest growing-stock volume, followed by two successional species, *Inga vera* and *Cecropia* (Fig. 9). The other common species are generally located in or near the primary forest.

Dacryodes clearly has the highest grade of sawtimber, with 64 percent of the wood in grade 1 logs (Table 16). The proportion of sawtimber in grade 1 logs for all other species is 19 percent, with 50 percent in grade 2 logs and 30 percent in grade 3 logs.

Management Opportunities for Natural Forests

With population growth, domestic water demands will increase. Likewise, future expansion of tourism or the introduction of small industry on the island will create greater demands for water. The continuous supply of good quality water throughout the year is dependent on maintaining forest cover on government-owned lands in the interior. These lands should be protected against further intrusion and plantations should be established on steep slopes to conserve water, and to reduce soil erosion and reservoir sedimentation.

The minimum stocking standard for Puerto Rico is 250 saplings or 100 poletimber-size trees per hectare of desirable species to assure reasonable stocking of a timber stand at maturity. Young secondary forests in St. Vincent contain 10 times the number of saplings and twice the number of poletimber trees, but the vast majority are classed as rough cull trees and would not be good candidates for future crop trees (Table 17). This proportion is much higher than the 45 percent found in young secondary forests of Puerto Rico. Such poor stocking, regardless of species, indicates that management of natural regeneration at this early stage of stand development would be premature. Replacement of young secondary forests with plantation species could be accomplished easily by clearing the small trees and other inhibiting vegetation.

Stocking improves somewhat for secondary forests which average 281 saplings and 45 poletimber growing-stock trees (Table 17). There would be some stands with sufficient growing stock that could be improved by girdling or injecting rough cull trees and undesirable species. Species to favor because of wood quality would include Inga vera, Ficus citrifolia, Dacryodes, Chimarrhis, Tabebuia pallida, Guarea guidonia, Cordia sulcata, Meliosma herbertii, Sterculia caribaea, Andira inermis, and Nectandra coriaceae. Eugenia sintenissii and Cecropia should be removed or deadened, while some understory species such as Prestoea montana would not compete in the long run with the larger species favored for timber production. These could be left untreated.

The much better stocking of growing-stock trees in the mature forest indicates that natural selection processes would eventually favor the larger timber species. Growing-stock basal area averages 64 percent of all stocking in the mature forest, compared with 34 percent in secondary and 16 percent in the young secondary classes. Although more than half of the saplings in the mature forest are classed as growing stock, many are suppressed as shade-tolerant individuals that would probably not respond to release cutting.

In summary, the best prospects for management of natural forests to improve timber species stocking occur in secondary forest stands with adequate stocking of desirable saplings and poletimber. Implementation of natural forest management requires a detailed survey of the species composition of a particular stand, and some experience with how the individual species might respond to release. In the absence of additional applied research studies, it is not recommended that natural forest management be attempted.

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APPENDIX

Reliability of the Data

Reliability of the estimates may be affected by two types of errors. The first stems from the use of a sample to estimate the whole and from variability of the items being sampled. This is termed sampling error; it is susceptible to a mathematical evaluation of the probability of error. The second type--often referred to as reporting or estimating error--derives from mistakes in measurement, judgment, or recording, and from limitations of methods or equipment. This type of error is held to a minimum by proper training, supervision, and precision.

Statistical analysis of the data indicates a sampling error of plus or minus 3.6 percent for forest area. Timber volume sampling error was estimated to be 19.1 percent. As theses totals are broken down by species, tree size, or other classifications, the possibility for error increases and is greatest for the smallest subdivisions.

DEFINITIONS

Forest land.--Land at least 10 percent stocked by forest trees of any size, or formerly having had such tree cover and not currently developed for nonforest use. The minimum area for classification of forest land is 1/2 hectare, and the minimum width for forest strips is 35 meters. Unimproved roads and trails, streams, and clearings in forest areas are classed as forest if less than 35 meters in width.

Timberland.--Forest land that is producing or is capable of producing crops of industrial wood and not withdrawn from timber utilization.

Other forest land.--Forest land incapable of yielding crops of wood because of adverse site conditions, forest land withdrawn from timber utilization through statute or administrative regulation, or forest land with higher priority use.

Nonstocked land.--Commercial forest land less than 10 percent stocked with growing-stock trees. This includes areas covered by inhibiting vegetation (brush, vines, ferns, etc.) classed as forest land.

Secondary forest.--Forest resulting from the abandonment of cropland or pasture, and forest resulting from the regeneration of previously cutover or disturbed forest land.

Palm forest.--Nearly pure stands of *Prestoea montana* which form in upper mountain regions.

Dwarf forest.--Also known as cloud forest or elfin woodland, the dwarf forest is found on the summits of the highest mountains and is characterized by densely packed, knarled trees less than 7 meters tall.

Dry forest.--Fine woody vegetation generally less than 10 meters tall at maturity, found under dry conditions typical of the Subtropical Dry Life Zone and certain serpentine and limestone soils.

Primary forest.--Relatively undisturbed, mature, wet or rain forest composed of mixed tree sizes. The canopy is generally higher than 7m.

Growing-stock trees.--Sawtimber trees, poletimber trees, saplings, and seedlings; that is, all live trees except rough and rotten trees.

Rough and rotten trees.--Live trees that are unmerchantable for sawlogs now or prospectively because of defect or rot.

Sawtimber trees.--Growing-stock trees, 22.5 centimeters and larger in dbh for softwoods and 27.5 centimeters and larger for hardwoods, and containing at least one 3.5 meter sawlog.

Poletimber trees.--Growing-stock trees 12.5 to 22.5 centimeters in dbh for softwoods and 12.5 to 27.5 centimeters for hardwoods, and of good form and vigor.

Saplings.--Growing-stock trees 2.5 to 12.5 centimeters in dbh, and of good form and vigor.

Volume of sawtimber.--Net volume of the sawlog portion of sawtimber trees in cubic meters, calculated according to the International rule, 0.635 centimeter (1/4 inch) kerf.

Volume of growing stock.--Volume of sound wood (less cull volume) in the bole and branches of sawtimber and poletimber trees from stump to a minimum 10 centimeter diameter outside bark or to the point past which a one-meter section meeting minimum qualifications can no longer be measured because of limbs or other cull.

Volume of timber.--Volume of all sound wood (including sound cull) in the bole and branches of growing-stock, rough, rotten, and salvable dead trees 12.5 centimeters and larger in dbh, from stump to a minimum 10 centimeters diameter outside bark. The minimum length of any section included is one meter.

Basal area.--The area in square meters of the cross section at breast height of a single tree or of all the trees in a stand, expressed as square meters per hectare.

Dbh (diameter at breast height).--Tree diameter in centimeters, outside bark, measured at 1.3 meters above ground.

Tree Species Tallied in St. Vincent, 1984.

Code	Scientific name	St. Vincent common name
037	*Andira inermis* W. Wright H.B.K.	Black plum, Jumbie mango
056	*Artocarpus altilis* Parkinson Fosberg	Breadfruit
137	*Canella winterana* L. Gaertn.	Wild cinnamon
160	*Cassipourea guianensis* Aubl.	
166	*Cecropia peltata* L.	Trumpet tree
193	*Citharexylum fruticosum* L.	Fiddlewood
207	*Citharexylum spinosum* L.	Bastard fiddlewood
225	*Cocos nucifera* L.	Coconut
242	*Cordia collococca* L.	Red manjack
244	*Cordia sulcata* DC.	White manjack
259	*Cyathea arborea* L. J.E. Smith	Tree fern, jamen joe
263	*Cyrilla racemiflora* L.	Bloodwood
291	*Dacryodes excelsa* Vahl	Gommier
293	*Daphnopsis americana* Mill. J.R. Johnston	Local mahoe
364	*Eugenia procera* Sw. Poir.	
368	*Eugenia sintenisii* kiaersk.	Bashi Guava
374	*Prestoea montana* R. Grah. Nichols.	Palm
403	*Faramea occidentalis* L. A. Rich.	Wild coffee
407	*Ficus citrifolia* Vahl	Wild fig
424	*Ficus obtusifolia* H.B.K.	Fig
436	*Guarea guidonia* L. Sleumer	Black plum
447	*Guettarda scabra* L. Vent.	
461	*Hedyosmum arborescens* Sw.	
514	*Inga vera* Willd.	Spanish ash
518	*Ixora ferrea* Jacq. Benth.	Wild coffee
549	*Linociera caribaea* Jacq. Knobl.	Mastic
570	*Mangifera indica* L.	Mango
572	*Manilkara bidentata* A. Dc. Chev.	Bulletwood, balata
594	*Meliosma herbertii* Rolfe	Wild cocoa
622	*Micropholis chrysophylloides* Pierre	Wild star apple
640	*Myrcia deflexa* Poir. Dc.	Wild plumrose
671	*Nectandra coriacea* Sw. Griseb.	Sweetwood
682	*Ochroma pyramidale* Cav. Urban	Balsa, bafal
687	*Ocotea leucoxylon* Sw. Mez	Sweetwood
735	*Phoebe elongata* Vahl Nees	Sweetwood
785	*Pouteria multiflora* A. DC. Eyma	Penny piece
850	*Sapium caribaeum*	Burn lime
897	*Symplocos martinicensis* Jacq.	Sweet leaf
908	*Tabebuia pallida* Dc. Britton	White cedar
949	*Guapira fragrans* Dum.-Cours. Standley	Mapoo, loblolly

Code	Scientific name	St. Vincent common name
1001	*Sloanea caribaea* Kr. and Urb.	Santinay
1002	*Sloanea massoni* Sw.	Boo wood
1003	*Ormosia monosperma* (Sw.) Urb.	Sarinette
1004	*Actinostemen caribeus* Griseb.	
1005	*Pithecellobium jupunda* (Willd.) Urb.	Wild tamarind
1006	*Talauma dodecaceptala* (Lam.) Urb.	Wild breadfruit, wild almond
1007	*Miconia virescens* (Vahl.) Triana	Torchwood
1008	*Miconia elongata* Vahl.	Candlewood
1009	*Chimarrhis cymosa* Jacq.	Waterwood
1010	*Croton populifolius* Lam.	Black siege
1011	*Lonchocarpus violaceus* H.B.K.	Greenhart
1012	*Simaruba amara* Aubl.	Board wood
1013	*Erythroxylon squamatum* Sw.	
1014	*Freziera hirsuta* Sm.	Gunstock
1015	*Inga ingoides* (Rich) Willd.	Spanish ash
1016	*Sterculia caribaea* R. Br.	Mahoe
1017	*Conomorpha peruviana* A.D.C.	
1018	*Acanthaeaceae* (Sp. unknown)	
1019	*Rubiaceae* (Sp. unknown)	
1020	*Licania ternatensis* Hook. F.	Bois job

UNIT CONVERSION FACTORS

Metric to English and English to Metric Conversions

1 cm. = 0.3937 in.	1 in. = 2.54 cm.
1 m. = 3.281 ft.	1 ft. = .3048 m.
1 km. = .6214 mi.	1 mi. = 1.6093 km.
1 sq. m. = 10.7639 sq. ft.	1 sq. ft. = 0.0929 sq. m.
1 sq. km. = 0.3861 sq. mi.	1 sq. mi. = 2.59 sq. km.
1 ha. = 2.471 ac.	1 ac. = 0.4047 ha.
1 cu. m. = 35.3145 cu. ft.	1 cu. ft. = 0.0283 cu. m.
1 sq. m. per ha. = 4.356 sq. ft./ac.	1 sq. ft./ac. = 0.2296 sq. m./ha.
1 cu. m. per ha. = 14.29 cu. ft./ac.	1 cu. ft./ac. = 0.07 cu. m./ha.

METRIC INVENTORY STANDARDS

Item	Metric standard
Prism size	BAF 2.5
Grid spacing	3 km.
Cluster point spacing	25 m.
Fixed plot size	40 $m.^2$ (r = 3.6 m.) 15 $m.^2$ (r = 2.2 m.)
Breast height	1.3 m.
Stump height	30 cm.
Diameter classes	5 cm. = 2.5 to 7.5 cm. dbh 10 cm. = 7.5 to 12.5 cm. dbh 15 cm. = 12.5 to 17.5 cm. dbh 20 cm. = 17.5 to 22.5 cm. dbh etc.
Tree size classes	
Sapling	2.5 to 12.5 cm. dbh
Poletimber (hardwood)	12.5 to 27.5 cm. dbh
Sawtimber (hardwood)	27.5 cm. + dbh
Sawtimber (softwood)	22.5 cm. + dbh
Minimum top D.O.B.	
Cubic volume	10 cm.
Hardwood sawlog	22.5 cm.
Softwood sawlog	17.5 cm.
Sapling	2.5 cm.
Minimum D.I.B. sawlog	
Hardwood	20 cm.
Softwood	15 cm.
Minimum length	
Cubic section	1 m.
Sawlog	2.5 m.
Sawtimber tree	3.5 m. sawlog