DEVELOPMENT, FORESTRY, AND ENVIRONMENTAL QUALITY IN THE EASTERN CARIBBEAN An Institute of Tropical Forestry Publication ---Page Break--- ---Page Break--- TABLE OF CONTENTS ---Page Break--- ---Page Break--- Preface In 1982 the U.S. Agency for International Development contracted the Institute of Tropical Forestry to conduct 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 Faaborg 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 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. Teland cooperators made the project possible through their goodwill, 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 timetable 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 B. Lugo Project Leader Rio Piedras, Puerto Rico September 14, 1985 ---Page Break--- Table 1. Timetable of activities Listing of personnel involved. Agency Personnel Activity Department of Agriculture R. Anthony Planning meeting at the Dunbars = Antigua Institute of Tropical Forestry Department of Biology J. Fasbors Division of Biological Sciences University of Missouri Columbia, MO 65211 Department of Natural Resources D. Jiménez Forest Service R. Schmidt P.O. Box 5887 San Juan, PR 00906 Forestry Division F. Gregoire Botanical Garden Roseau, Dominica Forestry Division Ministry of Agriculture and Trade Kingstown, St. Vincent Island Resources Foundation and Virginia Institute of Marine Science Box 254 Gloucester, VA 23061 Ministry of Agriculture, Food and Consumer Affairs Graeme Hall Christ Church, Barbados The Ministry of Agriculture Forestry Division Castries, St. Lucia US Agency for International Development Port-au-Prince, Haiti, or c/o American Embassy Harry Truman Blvd Port-au-Prince, C.F. Nicholls M. Nichols B. Payne G. Charles J. Talbot ---Page Break--- Table 1. (cont'd) Agency Personnel Activity USDA Forest Service Caribbean National Forest P.O. Box AQ Rio Piedras, PR 00928 USDA Forest Service Southern Forest Experiment Station 10210, US Postal Services Bldg. 701 Loyola Avenue New Orleans, LA 70113 USDA Forest Service Southern Forest Experiment Station

Institute of Tropical Forestry P.O. Box AQ Rio Piedras, PR 00928 US Geological Survey Water Resources Division US Department of the Interior Box 4424 San Juan, PR 00936 United Nations

Environment Programme Palais des Nations 1211 Geneva 10 Switzerland Department of Natural Resources San Juan, PR 00906 Environmental Quality Board P.O. Box 11488 Santurce, PR 00910 USDA Forest Service Caribbean National Forest Box 21 Palmer, PR 00721 B.D. Maldonado J.E. Makes Liv. Desselle W. Arendt Lik. Liegel A.E. Lugo P.L. Weaver A.S. Rodriguez + Gonzales-Liboy I. Stewart Vivaldi S. Woodbury L. Matos M. Rivera F. del Valle J. Bauer D.L. Bolinger J. Lefebre M. Maldonado I. Rivera L. Santoyo J. Zanbeas First and second training courses for junior Caribbean foresters ---Page Break--- Table 1. (cont'd) Agency Personnel Activity USDA Forest Service Caribbean National Forest P.O. Box AQ Rio Piedras, PR 00928 USDA Forest Service Southern Forest Experiment Station Institute of Tropical Forestry P.O. Box AQ Rio Piedras, PR 00928 USDA Forest Service Southern Region (R-8) 1720 Peachtree Road, NW Atlanta, GA 30367 US Fish and Wildlife Service Luquillo Experimental Forest Box 21 Palmer, PR 00721 US Geological Survey Water Resources Division US Department of the Interior Box 4424 San Juan, PR 00936 US Soil Conservation Service G.P.O. Box 48368 San Juan, PR 00936 Collaborator (San Juan, PR) Antigua Archaeological Society St. John's, Antigua Department of Agriculture Dunbars, Antigua B.D. Maldonado S.E.L. Maton J.B. Feheley B.C. Figueroa S. Jimenez F. Torres P.L.M. Wadsworth P.L. Weaver C. Dissmeyer J. Wiley P. McKinley A. Sierra J. Rodriguez Vidal D.V. Nicholson Wildlife Assoc. Caribbean R. Williams ---Page Break--- Table 1. (cont'd) Agency Personnel Activity Department of Biology M. Davis Division of Biological Sciences J. Faaborg, University of Missouri J. Faaborg, Columbia, MO 65211 J. King Forestry Division F. Gregoire Botanical Garden I.C. Maximea Roseau, Dominica Forestry Division C.A.P. Nicholls Ministry of Agriculture and Trade Kingstown, St. Vincent

Ministry of Agriculture, Food 1B. Payne and Consumer Affairs Graeme Hall Christ Church, Barbados Ministry of Agriculture Ws Johnson Plymouth, Montserrat Ministry of Agriculture, Lands, Re Wilkin Housing and Development. Vv. Williams Basseterre, St. Kitts K. Martin EL Petty The Ministry of Agriculture P. Butler Forestry Division G. Charles tries, St. Lucia US Agency for International 3. Talbot Development Port-au-Prince, Haiti, or c/o American Embassy Marey Truman Blvd. Port-au-Prince, Haiti USDA Forest Service AL Arendt Southern Forest Experiment W. Arendt Station ALE. Lugo Institute of Tropical Forestry P.O. Box AQ Rio Piedras, PR 00928 ---Page Break--- Table 1. (cont'd) Agency Personnel Activity USDA Forest Service W. Cleckley Southern Forest Experiment Station Forestry Sciences Laboratory Box 906 Starkville, MS 39759 Wider Caribbean Sea Turtle J. Fuller Recovery Team St. Johns, Antigua collaborator D. Gibbs USDA Forest Service Asks Lugo Watershed planning trip Southern Forest Experiment to the islands station Institute of Tropical Forestry P.O. Box AQ Rio Piedras, PR 00928 US Geological Survey R. Curtis Water Resources Division US Department of Interior Box 4424 San Juan, PR 00936 P. Vias Preparing and shipping of V. Hernández river gaging stations L. Santiago A. Curtis Installation of river P. Diaz gaging and rainfall stations G. Arroyo and training for collection of water and operation of Center for Energy and W. McDowell Environment Research Terrestrial Ecology Division P.O. Box 3682 San Juan, PR 00936 ---Page Break--- Table 1. (cont'd) Agency Personnel Activity US Geological Survey Visits to maintain river Water Resources Division gaging and rainfall US Department of Interior stations. Routine station operation and water sampling by island forestry personnel including G. Cordice in St. Vincent and A. James in Dominica T.M. Concepción R. Curtis P. Diaz P. Vias L. Santiago Forestry Division A. Gallion Field work on documentation Botanical Garden P. Gregoire of hurricane damage Roseau, Dominica Al

Janes to forests 8. John M. Metor R, Winston ‘The Ministry of Agriculture Ms. Andrew Forestry Division M. Bobb Castries, St. Lucia W. Felix USDA Forest Service A.L. Lugo Southern Forest Experiment A.L. Rodriguez Station Institute of Tropical Forestry P.O. Box AQ Rio Piedras, PR

00928 Lill, Liegel analysis of data on hurricane effects on A.L. Lugo A. Rodriguez P.L. Weaver Forest inventory planning trip to St. Vincent and the Grenadines USDA Forest Service R.A. Birdsey Southern Forest Experiment Station Forestry Sciences Laboratory Box 906 Starkville, MS 39759 ---Page Break--- Table 1. (cont'd) Agency Personnel Activity Forestry Division G. Beache Inventory of plantations Ministry of Agriculture E. Connor in St. Vincent and Trade G. Cordice Grenadines Kingstown, St. Vincent C.F. Nicholle L. Quammie J.T. Valenta USDA Forest Service C. Rivera Southern Forest Experiment P.L. Weaver Station Institute of Tropical Forestry P.O. Box AQ Rio Piedras, PR 00928 USDA Forest Service W. Checkley Southern Forest Experiment Station Forestry Sciences Laboratory Box 906 Starkville, MS 39759 Forestry Division G. Beache Field work for forest Ministry of Agriculture B. Connor inventory and Trade G. Cordice Kingstown, St. Vincent L. Quammie J.T. Valente USDA Forest Service C. Rivera Southern Forest Experiment Station Institute of Tropical Forestry P.O. Box AQ Rio Piedras, PR 00928 USDA Forest Service W. Cleckley Southern Forest Experiment Station Forestry Sciences Laboratory Box 906 Starkville, MS 39759 USDA Forest Service P.L. Weaver analysis of Southern Forest Experiment inventory data Station Institute of Tropical Forestry P.O. Box AQ Rio Piedras, PR 00928 ---Page Break--- Table 1. (cont'd) Agency Personnel Activity USDA Forest Service R.A. Birdsey Southern Forest Experiment Station Forestry Sciences Laboratory Box 906 Starkville, MS 39759 ---Page Break--- Birdsey, Richard A. USDA Forest Service Southern Forest Experiment Station Forestry Sciences Laboratory Box 906 Starkville, MS 39759 Diaz, Pedro L. US

Geological Survey Water Resources Division US Department of Interior Box 4424 San Juan, PR 00936 Liegel, Leow E. USDA Forest Service Experiment Station Institute of Tropical Forestry P.O. Box AQ Rio Piedras, PR 00928 (Current Address) Pacific Northwest Research Station 3200 Jefferson Way Corvallis, OR 97331 Lugo, Ariel B. USDA Forest Service Southern Forest Experiment Station Institute of Tropical Forestry P.O. Box Rio Piedras, PR 00928 CONTRIBUTORS McDowell, William H. Center for Energy and Environmental Research Terrestrial Ecology Division G.P.O. Box 3682 San Juan, PR 00936 (Current Address) SURCO Kinge Hall SUNY Oswego, NY 13126 Nicholls, Calvin F. Ministry of Agriculture and Trade Kingstown, St. Vincent Weaver, Peter L. USDA Forest Service Experiment Station Institute of Tropical Forestry P.O. Box AQ Rio Piedras, PR 00928 -10- ---Page Break--- 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 island. 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 Troumasse 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 Buccasent 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 Buccasent River; and from 0 to 320 mg/l on Trounassee 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, 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 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 Buccasent and the Trounassee 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, Trounassee, and Buccasent Rivers were (respectively): $y = 1.29x^{1.343}$ ($r^2 = 0.84$), $y = 0.67x^{1.11}$ ($r^2 = 0.85$), and $y = 0.62x^{1.20}$ ($r^2 = 0.79$). 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 rainforest streams. With the exception of nitrate and ammonia in the Buccament River, nutrient concentrations are generally low. Higher nitrogen concentrations in Buccament River are presumably due to higher population density along

the river's 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 a 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 PR83-1, 302 p.

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Table 2. Stream discharge by unit drainage area.
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Trounassee River, St. Lucia 5.46 23.3 4.29
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16 22 29 5 12 19 26 3 OCTOBER NOVEMBER DECEMBER 1984 Rainfall-Runoff relation at Layou River basin during October and November 1984. 4 ---Page Break--- 0001 ONOO3S 83d 1334 O18ND NI "JONVHOSIO YBIVM SNOINVINVISNI 001 oot a wanwradtvnneat = THiTRIT o aT « NOUWNVTdx3, AVG €3d SNOL NI 'JOBVHOSIO ANGWIGIS~GION3USNS SNOINVINVISN! ---Page Break--- SQL YOg-wE *yO-Z2 "EIB 9ENE"(3/R "> 950°C) 4/25 ™ OL ErB6K "LT Ak (6/8 > ¥16°2) 5 m0 soy 'sstarmeyp mre co ast 2 sao oy © 0 ar Comms) © Gp Gre 5 Homes dou oyylestodon nony To4oy wos seve anoge (© £59) °25 O61 a009e WF afeR 50 apeapaTy. "29pLo08x ofeae-L8IM-—"20V9 "ao wena 02 yg6t eEME—"OROAE 40 COTE, soioome aowvensia-sziye "(ends roy) eb 9'0 pur oterrsa ner wos sansa tou (wn €°8) 96 2° OPI 19 OE 5,02 "en yon 'aaviva n0u"1 AY MBArE noxTT_ oDpyCz19008 SITLUW ass 'orRTIEN -26- ---Page Break--- "S861 "8 "24Y (6/m m2 OBI") 5/25 92 £79 FyaGI EZ SORE (4/8 ND ZzI"0) 5/25 = Cry "soELEWETE amMTETH rbtoneoneh ov 30 porsee 5 aBS64 seer be yan) ee be een somnie oe ---Page Break--- £ 2 om nin wea Wat te ot ir aunngs 94 avis gest090 sxaonia "ES" "Snowmas WN sane EBWOONG 90% NorsiAIa SIOHNOSTE HELIN - AaAANS "WOTDOTOGS - YOTEALNT JO LNSKTAVEIG SALVEs GALINA ---Page Break--- ete aay gownrea Tr AuNng> 94 alvEs wucontA "38" Syoumeds BV scant NOTSTAT SHOMNOSTY HELM - AaAANS 1WOTOOTOGD - YOTERINT JO WERE SALES = ---Page Break--- waa wwe oan nono aa sara wean POT MOMELLESS OF CET KIMI WGA MAIN "UNOOGS Ma IAA OTEND I "ZONMOSTG WING TWHOTSIAONE rez sveey gomnrvad Ut auungs _9¢ anezs vOliWOG "krava HON av acl ---Page Break--- as ow ua oee eat wags wet cara evar SEX HIMELEIS OF YOST HANOI WGK NAIM "CNOCES MES LEAS O1GND NE" ee Nene gownrvea Tt aunno> 9x anvas ¥rez190 on0T NOINIWOR! "AITIVA OAV a ACMA HOA OO MM: NOISTAIG Saounosay MAL - AaAWNS IWOT01039 - HOTYSINT 40 IAGMDAVEIG ALVES GITNN ---Page Break--- Bt poy 2 aeama68 C0) a3 ---Page Break--- waa we saw sania wow Poot AcIMELEAIS O% CO6t eIMOEDO MAA wAEYM "GNOIAS Meld Axia O1aND NI "goKWOSTA bees ey sovurvua tet auuno9 az auvas 9215090 ono7 inna

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THE FOREST RESOURCES OF ST. VINCENT

Richard A. Birdsey, Peter L. Weaver, and Calvin F. Nicholls

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

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

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ACKNOWLEDGEMENTS

This project was partially funded by the U.S. Agency for International Development as part of the U.S. Government's contribution to the Caribbean Environmental Action Plan. The authors wish to acknowledge John T. Valenta, Peace Corps volunteer, for providing valuable assistance during inventory planning and fieldwork. St. Vincent Forestry department personnel assisted in sample plot location and

measurement. This essential service was provided by C. Cordice, L. Quamie, and E. Connor. Cleckley, U.S. Forest Service, was responsible for the difficult task of timber cruising, and Carlos Rivi, U.S. Forest Service, was responsible for tree species identification. Their assistance is greatly appreciated.

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 maize 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, 6%; European White, 4%; Amerindian, 2%; others, 4%. Population growth on the island since the mid-1800s has been classified into four major periods (Byrne 1969). From 1861 to 1881 and from 1911 to 1931, growth was moderate (Fig. 1). The intervening period had little population growth. Starting in the 1930s, 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/km². About 7,000 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 led to widespread planting of arrowroot on the island. * 1930s = 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 1900s, 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. ---Page Break--- 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 km². 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 km². The largest and most proximate to St. Vincent is Bequia, which covers 18 km². 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 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 high points at Richmond Peak, 1075 m, Mount Bisbane at 920 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 (Rowley 1979). It has apparently been erupting violently about once every 100 years for the last millennium. Historic eruptions have been characterized by nuées 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 a million years

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 of 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. 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 (Kalker 1937). The island is influenced by tradewinds, particularly during the winter months. The annual migration of the equatorial convectional rains, however, provides a well-defined June through November rainfall maxima (Fig. 3). The 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 1923). The comparatively dry season from January to 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 1890 and 1886, 2 slight ones in 1897, and a severe storm in 1898. A moderate 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 197 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 isohyetal 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 isohyets 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 1997). The soils of St. Vincent are derived mainly from loose, fragmental volcanic ejecta such as boulders, stones, cinders, sand, and ash (Hardy 1999). 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., 1924). 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 1700s sea island cotton was grown extensively on the island but at the beginning of the 1800s 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 1984a). Land tenure statistics as of 1944 for 177 km² 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, 34%; 40.1 to 400 ha, 35%; 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 ha (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 that 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 groundwater 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 4.53×10^8 gal./day and a wet intake capacity of 7.77×10^8 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, 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

Rainforest = The rainforest occupies small areas between 350 and 500 m elevation, principally in the headwaters of the Colonarie, Cumberland, and Buccament Valleys. The forest averages about 20 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 36 percent of the stems to the windward and is virtually absent to the leeward. The canopy dominants are Dacryodes excelsa, Lauraceae spp., Heliosna 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 600m on both sides of the central mountains. The forest is short, 4m 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, Miconia pinata, 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 8m. 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 germinans. Secondary communities Palm brake: The palm brake occupies exposed areas above 500m on both sides of the mountains. About 70 percent of the stems are palms that reach 12m 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 caribaeum, 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 eruptions 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 volcanism. 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 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, Piscidia 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 20m in some areas has developed. In addition to the hardwoods mentioned above, Tabebuia pallida, Swietenia mahagoni, Hymenaea 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 km2 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 have 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 km2 or slightly more than half the island. ---Page Break--- FOREST PLANTATION SURVEY Plantation Description Of the 50.6 ha of plantation for which we could find records, Hibiscus 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 1962). 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 m3/ha for 5-year-old Cordia at Government House to a surprising 575 m3/ha for 21-year-old Pinus at Hermitage (Table 3). In Young Men'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 2 terraces 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 1962 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 were 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 0.65 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 macrophylla 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: 53 ---Page Break--- © 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 (5m) 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. Ashe ---Page Break--- 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 fine 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 reconnaissance survey to provide ---Page Break--- 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 mean 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 12.8 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 12.8 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 1964). 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 1988). All definitions and inventory standards are listed in the appendix to this report, along with a

species list and some useful conversion factors. AVI 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. ANI 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

nature, mostly undisturbed primary rainforest. This and the undisturbed plain 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 rainforest 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 rainforest. 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 Soufrière, which accounts for much of the 2,750 hectares of unstocked or bare land. 58. ---Page Break--- 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 non-forest 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 three 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 varies considerably between the 3 timberland classes (Tables 9, 10, 11). Although the classes represent 3 stages of the 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 (poles 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 and Cecropia have persisted, and many have reached maturity. Guarea 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. For all classes of timberland combined, Inga vera comprises the most + Dacryodes and Cecropia. The largest dbh recorded was a Sloanea at 100 centimeters. The tallest tree was another Prestoea, Cecropia, Ficus, and Chrysophyllum. Basal area, followed by 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 usable 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, Actinostemon caribeus, and Talauma dodecandra 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 pole timber growing-stock trees (Table 17). Some stands have 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 Dacryodes, Chimarrhis, Tabebuia pallida, Guarea guidonia, Cordia sulcata, Meliosma, Inga vera, Ficus itrifolia, Sterculia caribaea, Andira inermis, and Nectandra coriacea. Eugenia sintenisii 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 pole timber. 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. ---Page Break--- LITERATURE CITED Adams, J. E. Maritime industry of the St. Vincent Grenadines, West Indies. The American Neptune. 32(3): 180-194; 1972. Adams, J. E. Shore whaling in St. Vincent

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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, pasture, and forest resulting from the regeneration of previously cutover or forest resulting from the abandonment of cropland or disturbed forest land. Palm forest.--Nearly pure stands of Prestoea montana which form in upper mountain regions. 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, gnarled 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, composed of mixed tree sizes. The canopy is generally higher than 7 meters. Growing-stock trees. Seedlings; that is, all live trees except rough and rotten trees. Relatively undisturbed, mature, wet or rain forest sawtimber trees, poletimber trees, saplings, and rough and rotten trees.--Live trees that are unmerchantable for sawlogs now or prospectively because of defect or rot. Sawtimber tree: Growing-stock trees, 22.5 centimeters and larger in diameter at breast height (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. Net volume of the sawlog portion of sawtimber trees. Volume of sawtimber 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 top.

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 vines or other cull. Volume of timber,--Volume of sound wood (including sound cull) in the bole and branches of growing-stock, rough, rotten, and salvageable 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. 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. ---Page Break--- Code 037 056 087 160 166 193 207 225 242 244 259 263 274 293 368 358 389 403 407 424 435 447 461 514 518 549 570 572 594 622 640 671 682 687 735 785 850 897 908 949 Tree Species Tallied in St. Vincent, 198 Scientific name Andira inermis W. Wright H.B.K. ‘Artocarpus altilis Parkinson Fosberg Canella winterana L. Gaertn. Cassipourea guianensis Aubl. Cecropia peltata L. Citharexylum fruticosum L. Citharexylum spinosum L. Cocos nucifera L. Condalia coccinea L. Condalia salicifolia DC. Cyathea arborea L. J.E. Smith Cyrilla racemiflora L. Dacryodes excelsa Vahl Daphnopsis americana Mill. Eugenia procera Sw. Poir. Eugenia vincenteae Kiaersk. Prestoea montana R. Graham. Nichols. Faramea occidentalis L. A. Rich. Ficus citrifolia Vahl Ficus obtusifolia H.B.K. ‘Guarea guidonia L. Sleumer Guettarda scabra L. Vent. Hedyosmum arborescens Sw. Inga vera Willd. Tetrazygia bicolor Cogn. Miconia caribaea DC. Knob. Mangifera indica L. Manilkara bidentata A. DC. Chev. Meliosma herbertii Rolfe Micropholis chrysophylloides Pierre Myrciaria floribunda Poir. DC. Nectandra coriacea Sw. Griseb. Ochroma pyramidale Cav. Urban Ocotea leucoxylon Sw. Nees Phoebe elongata Vahl Nees Pouteria multiflora A. DC. Eyma ‘Sapium caribaeum Hemsl. Symplocos martinicensis Jacq. Tabebuia pallida DC. Britton Guapira fragrans

Dun.-Cours. Standley J.R. Johnston St. Vincent Black plum, Jumbie mango Breadfruit Wild cinnamon Trumpet tree Fiddlewood Bastard fiddlewood Coconut Red manjack White manjack Tree fern, jane joe Bloodwood Gonsier Vocal mahoe Bashi Guava Palm Wild coffee Wild fig Fig Black plum Spanish ash Wild coffee Mastic Mango Bulletwood, balata Wild cocoa Wild star apple Wild plumrose Sweetwood Balsa, balsa 'Sweetwood Sweetwood Penny piece Burn Vine. Sweet leaf White cedar Mapoo, loblolly ---Page Break--- Code 1001 1002 1003 1008 1005 1006 1007 1008 1009 1010 1011 1012 1013 1018 1015 1016 1017 1018 1019 1020 Scientific name Sloanea caribaea Kr. and Urb. Sloanea massoni Sw. Ormosia monosperma (Sw.) Urb. Antinostemon caribaeus Griseb. Pithecellobium jupunba (Willd.) Urb. Talauma dodecapetala (Lam.) Urb. Miconia virescens (Vahl.) Triana Miconia elongata Vahl. Chimarrhis cymosa Jacq. Croton populifolius Lam. Lonchocarpus violaceus H.B.K. Simarouba amara Aubl. Erythroxylum echinatum Sm. Prestoea acuminata Willd. Inga ingoides (Rich) Willd. Sterculia caribaea R. Br. Connaropa peruviana A. Acanthaceae (Sp. unknown) Rubiaceae (Sp. unknown) Licania ternatensis Hook. f. St. Vincent common name Santinay Boo wood Sarinette Wild tamarind Wild breadfruit, wild almond Torchwood Candlewood Deerwood Black sage Greenheart Board wood Gunstock Spanish ash Mahoe Bois job ---Page Break--- UNIT CONVERSION FACTORS Metric to English and English to Metric Conversions cm. = 0.3937 in. km = 0.6214 mi. sq. m. = 10.7639 sq. ft. sq. km = 0.3861 sq. mi. ha = 2.471 ac. cu. m = 35.3145 cu. ft. sq. m. per ha = 4.356 sq. ft./ac. cu. m per ha = 14.29 cu. ft./ac. cu. ft. = 0.0283 cu. m. ft^3/ac = 0.2296 sq. m/ha. ft^3/ac = 0.07 cu. m/ha. METRIC INVENTORY STANDARDS Item Prism size Grid spacing Cluster point spacing Fixed plot size Breast height Stump height Diameter classes Tree size classes Sapling Pole timber (hardwood) Saw timber (hardwood) Saw timber (softwood) Minimum top D.O.B. Cubic volume Hardwood sawlog Softwood sawlog Sapling Minimum DBH Hardwood Softwood Minimum Length

Cubic section sawlog: Sawtimber tree + sawlog. Metric standard: 5 cm = 2.5 to 7.5 cm, dbh 10 cm = 7.5 to 12.5 cm, doh 15 cm = 12.5 to 17.5 cm, coh 20 cm = 17.5 to 22.5 cm, ddh etc. 2.5 to 12.5 cm, dbh 12.5 to 27.5 cm, abh 20.5 cm, dbh 22.5 cm, dbn 10 cm, 22.5 cm, 17.5 cm, 2.5 cm sawlog.
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