United States
Department of
Agriculture

Forest Service

# Estate Thomas Experimental Forest,

## St. Croix, U.S. Virgin Islands:

## *Research History and Potential*

**Peter L. Weaver**

**International Institute of Tropical Forestry**

General Technical
Report IITF-30

**Author**

**Peter L. Weaver,** Research Forester, U.S. Department of Agriculture, Forest Service, International Institute of Tropical Forestry, Jardín Botánico Sur, 1201 Calle Ceiba, San Juan, PR 00926-1119.

**Cover photo:** *Near Christiansted, Estate Thomas (top) has a history of forestry research dating back to the early 1950s. The Chittagong plantation (bottom left), once part of an array of plantings all over St. Croix, is a permanent study plot for students. The rare lignum-vitae (bottom right) has always been treasured for its attractive blue flowers and valuable wood. Today, both are part of the legacy that the island's residents and visitors may share at Estate Thomas.*

Top photo courtesy of U.S. Army Corps of Engineers 2004, bottom left and bottom right photos courtesy of Peter L. Weaver.

# Estate Thomas Experimental Forest, St. Croix, U.S. Virgin Islands:

## *Research History and Potential*

**Peter L. Weaver**

June 2006

**International Institute of Tropical Forestry**
Jardín Botánico Sur
1201 Calle Ceiba
San Juan, PR 00926-1119

# Contents


Page

**Abstract** ..... v
**List of Figures** ..... vi
**List of Tables** ..... vii
**Background Information** ..... 1
Introduction ..... 1
Objectives ..... 1
Legal and Administrative Details ..... 1
**Geology and Soils** ..... 3
Major Geologic Formations ..... 3
Major Soil Types ..... 4
**Physiography** ..... 4
**Climate** ..... 5
General ..... 5
Rainfall ..... 5
Temperature ..... 6
Relative Humidity, Evaporation, and Wind ..... 6
Hurricanes ..... 6
**Flora** ..... 7
**Fauna** ..... 14
Mammals ..... 14
Birds ..... 14
Reptiles and Amphibians ..... 15
Butterflies ..... 16
**Human Settlement** ..... 16
Pre-Columbian ..... 16
Settlement and Plantation Agriculture: 1625-1917 ..... 17
U.S. Involvement: 1917-2000 ..... 19
Population Trends: Residents and Tourists ..... 20
History: Sion Farm and Estate Thomas ..... 21
**Forest Service Activities: 1930-62** ..... 23
**Forest Service Activities: 1963-2000** ..... 31
Mahogany Provenance Trials (IITF Research Files 2421) ..... 31
Hybrid Mahogany ..... 33
Other Formal Mahogany Studies ..... 34


*continued*

## *Contents, continued*


*Cedrela* Provenance Trials (IITF Research Files 2450) ..... 34
Teak Provenance Trial (IITF Research Files 2473) ..... 34
Species Adaptability Trials (IITF Research Files 2394) ..... 35
Other Plantings ..... 35
Current Situation ..... 36
**Conservation, Education, and Demonstration** ..... 36
State and Private Forestry Documents ..... 37
State and Private Management Practices ..... 37
Highlighting Demonstration and Management ..... 38
Maintaining the Forestry Research Tradition ..... 38
Recreational Opportunities ..... 39
School Educational Programs ..... 39
**Other Protected Terrestrial Areas on St. Croix** ..... 40
Federal Government Properties ..... 40
U.S. Fish and Wildlife Service ..... 40
U.S. National Park Service ..... 42
Virgin Islands Government Properties ..... 44
Protected Parcels ..... 44
Virgin Islands Housing, Parks, and Recreation ..... 46
University of the Virgin Islands and the Virgin Islands Department of Agriculture ..... 46
Nongovernmental Organizations ..... 46
The Nature Conservancy ..... 47
St. Croix Environmental Association ..... 47
St. Croix Landmarks Society ..... 48
St. George Village Botanical Garden ..... 49
Heritage Trail Sites ..... 49
**The Role of Estate Thomas** ..... 50
**Acknowledgments** ..... 52
**Endnotes** ..... 53
**Literature Cited** ..... 53
**Appendix A**—Chronology of major events in the U.S. Virgin Islands, mainly St. Croix, with some details regarding Sion Farm and Estate Thomas ..... 59
**Appendix B**—Areas serviced by Virgin Islands Housing, Parks, and Recreation on St. Croix ..... 62

# Abstract

Three groups of Native Americans, the Ciboneys, Arawaks, and Caribs, reached the Virgin Islands in pre-Columbian times. Since their discovery by Columbus in 1493, the Virgin Islands have been held or governed by Spain, Britain, the Netherlands, France, the Knights of Malta, Denmark, and the United States. They have also been held or used by groups ranging from estate owners and trading companies to pirates and squatters. European settlement of St. Croix, which began about 1625, resulted in the gradual replacement of that island's native forest with agricultural estates. Estate Thomas, on St. Croix, has had various owners or managers: William Thomas and other individuals from 1749 to 1835, several government entities and two individuals from 1835 to 1963, and the U.S. Department of Agriculture Forest Service since 1963. The island's plantation economy is now history, and St. Croix has become a popular tourist destination. Sugar production and subsistence agriculture were the major land uses through the early 1950s. In 1953, the Institute of Tropical Forestry (now the International Institute of Tropical Forestry), then located in Río Piedras, PR, initiated tropical dry forest research throughout St. Croix, much of it on the 60-ha Estate Thomas. For the first 10 years, field experimentation centered around nursery techniques, seed germination, small-leaf mahogany regeneration and stand improvement, plantation establishment including small-leaf mahogany and teak, weed control, the determination of tree and stand growth rates, sawmilling, wood utilization, and the treatment of fence posts. After 1963, the Institute initiated several formal studies, some long term. These included provenance trials of mahogany (both big-leaf and Pacific Coast mahogany), Spanish cedar, and teak, as well as species adaptability trials. Other studies included hybrid mahogany growth, root pruning of mahogany nursery stock, thinning or frilling of unwanted competition in small-leaf mahogany stands, and plantings of the locally rare lignum-vitae. Although recent hurricanes have severely damaged property on St. Croix, Estate Thomas Experimental Forest survives in the middle of St. Croix, only a short distance from Christiansted, the Agricultural Experiment Station, the university, and the island's high school. The Estate remains a green area on a portion of the island otherwise saturated with houses, shopping plazas, and roads. Plans for the future of the Estate highlight its importance as an urban forest with a history in experimental forestry that links St. Croix with Latin America and Southeast Asia. Unparalleled opportunities exist for forestry education and demonstration, and passive recreation. On an island that treasures its colonial past, the unique history of Estate Thomas should be showcased for all Crucians to appreciate and cherish.



**Keywords:** Estate Thomas, forest research, lignum-vitae, mahogany, Sion Farm, St. Croix.

## *List of Figures*

**Figure 1**—Place names on St. Croix. Capital letters indicate sites used for forestry activities. ..... 2

**Figure 2** Estate Thomas geology and soils map. Kingshill marl underlies all of Estate Thomas along with surficial deposits (alluvium) in the central drainage (C). Soils are Arawak gravelly loam with different slopes: 5 to 12 percent (C), 12 to 20 percent (D), 20 to 40 percent (E), 40 to 70 percent (F). ..... 3

**Figure 3**—Estate Thomas topographic map with location of sites of interest. ..... 4

**Figure 4**—Population trends of settlers on St. Croix. (Sources: Anonymous 1950, Jensen 1998, Lawaetz 1991, Lewisohn 1970, Rogozinski 1999, U.S. Department of Commerce 2003, Westergaard 1917.) ..... 20

**Figure 5**—Sion Farm Great House, painting, circa 1860. (St. Croix Landmarks Society Library and Archives, Photograph Collection.) ..... 23

**Figure 6**—Map of major public areas and private protected properties on St. Croix, 2005 (locations are approximate, lacking ground proof). ..... 40

**Figure 7**—Estate Thomas and surrounding high-population-density areas, including the Sion Farm subdistrict and nearby Christiansted (U.S. Army Corps of Engineers 2004). ..... 50

## *List of Tables*

**Table 1**—Monthly rainfall and temperature normals, St. Croix, 1971-2000 ..... 5

**Table 2**—Plant species recorded at Estate Thomas ..... 9

**Table 3**—Mammal, bird, and reptile species recorded at Estate Thomas ..... 14

**Table 4**—Butterfly species that may be seen at Estate Thomas ..... 16

**Table 5**—Ownership, land use, and population on Sion Farm, 1750-1963 ..... 21

**Table 6**—General results of forestry activities (research and management) on St. Croix, 1952-62 ..... 25

**Table 7**—Additional forestry activities, mainly plantings, on St. Croix from 1954 to 1972 ..... 27

**Table 8**—Sites used by U.S. Department of Agriculture Forest Service on St. Croix for formal studies, field experiments, and operations ..... 29

**Table 9**—Major public and private properties on St. Croix and surrounding offshore islands managed as protected areas, including recreational areas, or with potential for such use ..... 41

# *Background Information*

## Introduction

The U.S. Virgin Islands in the West Indies occupy about 346 $km^2$. St. Croix, with an area of 221 $km^2$, is the largest island, followed by St. Thomas with 73 $km^2$ and St. John with 52 $km^2$. St. Croix has a long and complicated history under different nations. The island has been called Sancta Cruz (Latin); Santa Cruz (Spanish); and then Sanct. Croix, Sante Croix, and St. Crux (hybrids used by explorers); also Sainte Croix (French); Helling Kors (Danish); and finally, the current St. Croix (Lewisohn 1970). Local place names on St. Croix have many variants. Survey records for the island contain "lists of unpublished names; some newly proposed, others locally used, but of dubious orthography; still others, published with contradictory spellings; not to speak of different names for the same feature. Cartographers were confronted with all sorts of quandaries" (McGuire 1925, page 3). The confusion over place names persists today.

U.S. Department of Agriculture Forest Service activity on St. Croix dates back to the early 1930s when foresters stationed in Puerto Rico first visited the island. (Note: the name of the Forest Service unit in Puerto Rico has changed several times in the 20th century; to avoid confusion, it will be referred to by its current name, the International Institute of Tropical Forestry, or IITF). Forest Service involvement on St. Croix spans about 75 years, and its research and management activities at Estate Thomas about 50 years. Despite its limited presence on the island currently, many St. Croix residents (Crucians) strongly support the continued ownership, research, and management of Estate Thomas by the Forest Service.

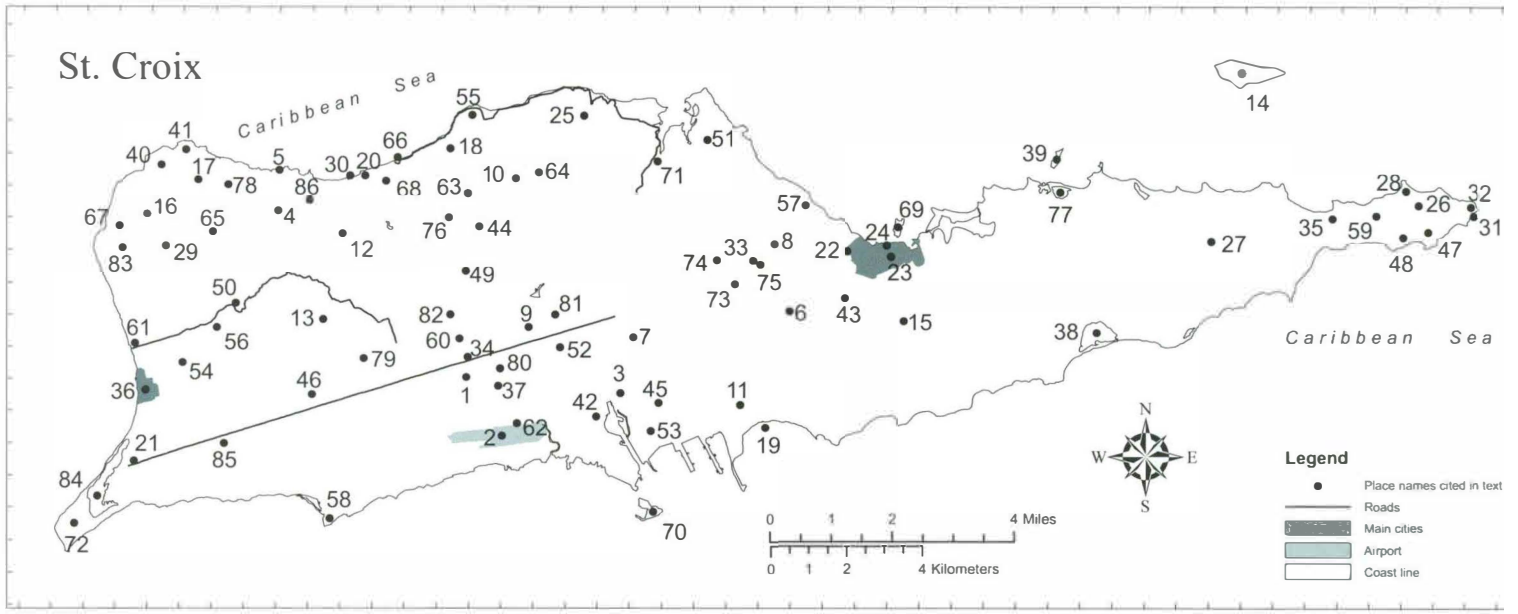
Plantation agriculture transformed St. Croix's landscape over the course of many decades, and subsistence agriculture continued on Estate Thomas until the mid-1950s. Today, commercial, residential, and tourist uses have replaced much of the agricultural demand for land. These changes have paved the way at Estate Thomas for an expanded forestry program, one that illustrates its history of multiple-use forest management and forestry research. The program should also highlight the Estate's future role as an outdoor laboratory for environmental education and interpretation aimed at the island's younger generation.

## Objectives

The purpose of this report is to provide a history of Estate Thomas and indicate its potential for additional forestry research along with demonstration, education, and recreation in an urban setting. This report describes the Estate's physical setting, climate, flora, fauna, and past IITF research, as well the history of settlement on St. Croix. Many IITF studies have used St. Croix as an important dry-zone planting site for comparisons with more humid areas in Puerto Rico. Since some of the research was regional in scope, St. Croix is linked to other Caribbean Islands and many continental countries from Mexico to Argentina. Some studies even used seeds imported from Southeast Asia. This report emphasizes the scope of research activities; detailed results are available in the original sources. Locations of places that are mentioned prominently in the text, including IITF research sites other than Estate Thomas, are indicated in figure 1. St. Croix's other protected areas are briefly described to show the unique role that Estate Thomas should play within the island's protected area system.

## Legal and Administrative Details

Tropical and subtropical dry forests (Holdridge 1967) occupy about one-half of the tropics, and human activity has heavily impacted them. Lacking dry forest within the Luquillo Experimental Forest of northeastern Puerto Rico, the Forest Service purchased the 59.7-ha Estate Thomas for research and demonstration. Research funds paid the total cost, $5,716.48. The quitclaim deed (number 4648) was dated March 28, 1963, from the Virgin Islands Corporation (VICORP), a land-holding entity of the U.S. Government on St. Croix. On May 21, 1964, the title was entered in book 30, page 335, document number 1224, of the St. Croix Record of Deeds Office as follows: "United States of America for the benefit of the Forrest [sic] Service Department of Agriculture, by Quitclaim Deed dated March 28, 1963, from the Virgin Islands Corporation, convey this Estate." The boundaries of the rectangular tract conform to the estate system of land subdivision established by the Danish after purchasing the island in 1733. The Oxholm Map of 1794, which still serves as the most widely used cadastral map




1. Adventure Trail
2. Airport (Henry E. Rohlsen)
3. Alcoa
4. ANNALY
5. ANNALY BAY
6. Anna's Hope
7. Barren Spot
8. BELLVUE
9. BETHELEM NEW WORKS
10. BETZY'S JEWEL
11. Billy French Ponds
12. BODKINS
13. BOG OF ALLEN
14. Buck Island
15. BUGBYHOLE
16. Butler Bay
17. Caledonia
18. CANE BAY
19. Canegarden Bay
20. Carambola Beach Resort
21. Centerline Road
22. Central Factory (Richmond)
23. Christiansted
24. Christiansted Nat. Hist. Site
25. Clairmont
26. Cotton Garden
27. COTTON VALLEY
28. Cramer's Park
29. Creque Dam
30. DAVIS BAY
31. East End Bay
32. East Point (Udall Point)
33. ESTATE THOMAS
34. Experiment Station (Agriculture)
35. Fairleigh Dickenson University
36. Fredericksted
37. Golden Grove
38. Great Pond
39. Green Cay
40. HAMS BAY
41. HAMS BLUFF
42. Harvey Aluminum (St. Croix Alumina)
43. Hermon Hill
44. Hermitage Valley
45. Hess Oil Refinery
46. Hogensborg
47. Isaac's Bay
48. Jack's Bay
49. JEALOUSY
50. JOLLY HILL
51. JUDITH FANCY
52. KINGS HILL
53. Krausses Lagoon
54. La Grange
55. La Vallee
56. Little La Grange
57. Little Princess
58. Long Point
59. Longpoint Estate
60. LOWER LOVE
61. MAHOGANY ROAD
62. MANNINGS BAY
63. Mt. Eagle
64. Mt. Pleasant
65. MT. VICTORY
66. North Shore Road
67. Prospect Hill
68. Prosperity
69. Protestant Cay
70. Ruth Cay
71. SALT RIVER
72. Sandy Point
73. SION FARM
74. SION HILL
75. SION RIDGE
76. SOLITUDE
77. Southgate Pond
78. SPRING GARDEN
79. St. Georges
80. University of the Virgin Islands
81. Upper Bethelem
82. Upper Love
83. Washington Hill
84. West End Salt Pond
85. Whim Estate
86. Wills Bay

Figure 1—Place names on St. Croix. Capital letters indicate sites used for forestry activities.

for St. Croix, delineated the Estate's boundaries and location (Hutchins and others 1990). The size of Estate Thomas is an artifact of the original property measurements done on St. Croix in Danish units (McGuire 1925).

On March 11, 1964, the Chief of the Forest Service designated Estate Thomas as an Experimental Forest (Adams and others 2004). The Estate has neither National Forest status nor is it part of the Caribbean National Forest in Puerto Rico; however, it is a component of the national forest system. The IITF in Puerto Rico began field experiments on the Estate as early as 1953 and has administered the area since 1963. From the mid-1960s through the mid-1970s, the IITF initiated several long-term formal studies on the Estate, mainly species adaptability and provenance trials. The IITF has carried out all activities in cooperation with the Virgin Islands government.

Since the mid-1990s, Forest Service activities on St. Croix have been run mainly through the IITF's State and Private Forestry (S&PF) program. Caribbean National Forest personnel have made infrequent visits to the Estate for law enforcement and timber sales, and research personnel have done follow-up on established studies. The S&PF program has a number of partners, including the Virgin Islands Department of Agriculture, the Fire Service, the Resource Conservation and Development Council, the Cooperative Extension Service, and nongovernmental organizations (NGOs). These partnerships develop local capacity in urban and community forestry, landowner assistance, economic action, cooperative fire protection, and forest health. Although S&PF funding is not available for forest management or research at Estate Thomas, other opportunities exist for cooperation.

## *Geology and Soils*

### Major Geologic Formations

St. Croix has a long and complex geologic history (Cederstrom 1941, 1950; Whetten 1966, 1974). The island's rocks are metamorphosed volcanics from the Cretaceous period, limestones, and intrusive diorite overlain by Tertiary clay and limestone. About 80 million years ago during the late Cretaceous, debris from eroding volcanic rocks and volcanic ash were thrown into the air and later deposited as sedimentary rock on the ocean floor.

Folding and igneous activity caused mountain formation, probably during the Eocene, and this activity was followed by subaerial erosion. By the middle Oligocene, most of the island was submerged where it remained until the Miocene. Sediments deposited during the Miocene were uplifted, bringing them into contact with older deposits. Presently, these rocks underlie the island's mountain ranges and possibly the Central Valley.

Five broad categories of rock formations occur on St. Croix, including the Kingshill marl in the Central Valley (Whetten 1966, 1974). Kingshill marl, the early Miocene limestone underlying Estate Thomas, was formed about 20 million years ago as part of a coral reef when the island was uplifted. The Kingshill formation lies flat or is gently folded and consists of a complex, thick, extensive shelf-edge marl with submarine debris flows, shallow water corals, and land-eroded sediments, as well as frequent calcareous sandstone beds (Curth and others 1974). Recent surficial deposits (alluvium) cover about 5 percent of the marl along the western part of the main drainage on Estate Thomas (fig. 2).

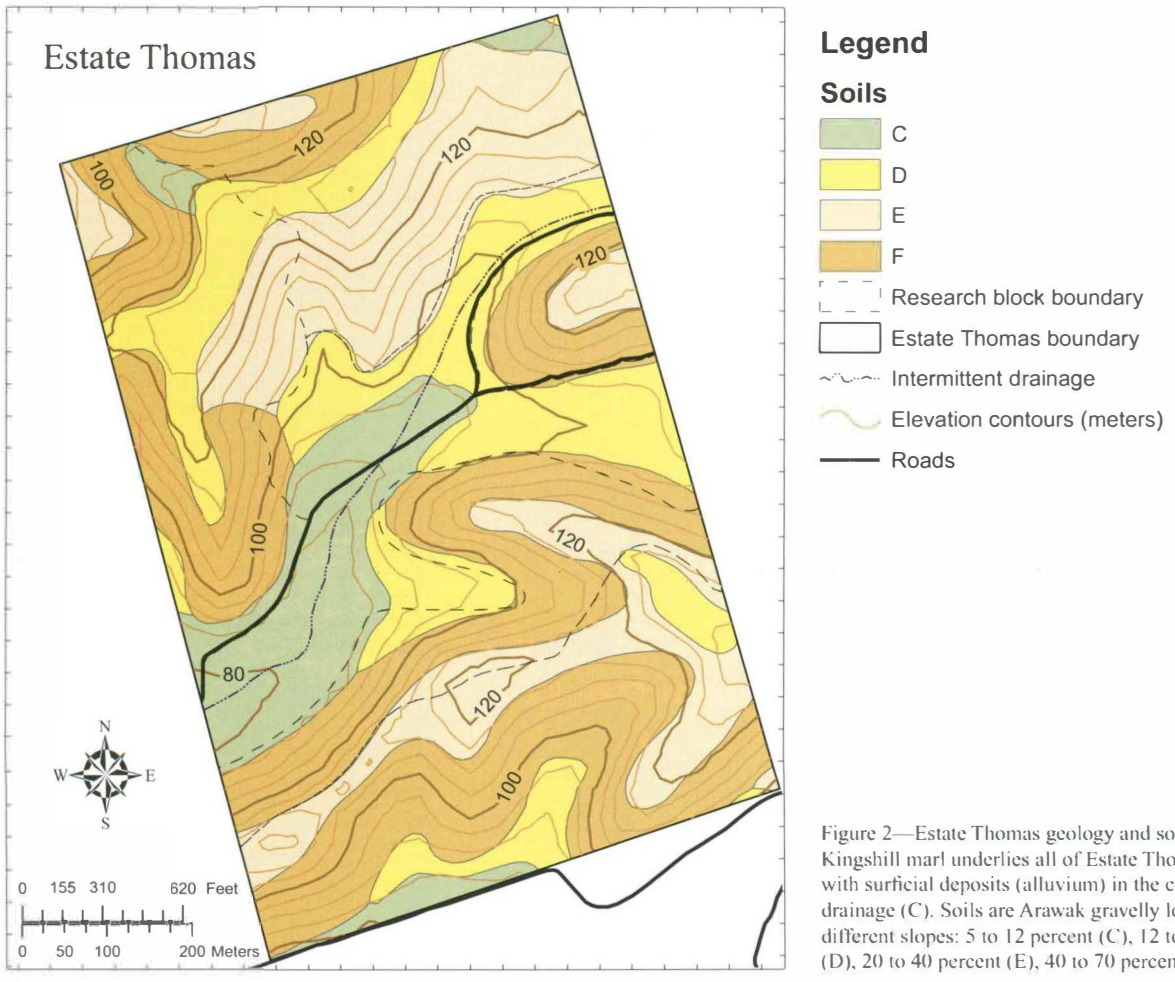



Figure 2—Estate Thomas geology and soils map. Kingshill marl underlies all of Estate Thomas along with surficial deposits (alluvium) in the central drainage (C). Soils are Arawak gravelly loam with different slopes: 5 to 12 percent (C), 12 to 20 percent (D), 20 to 40 percent (E), 40 to 70 percent (F).

## Major Soil Types

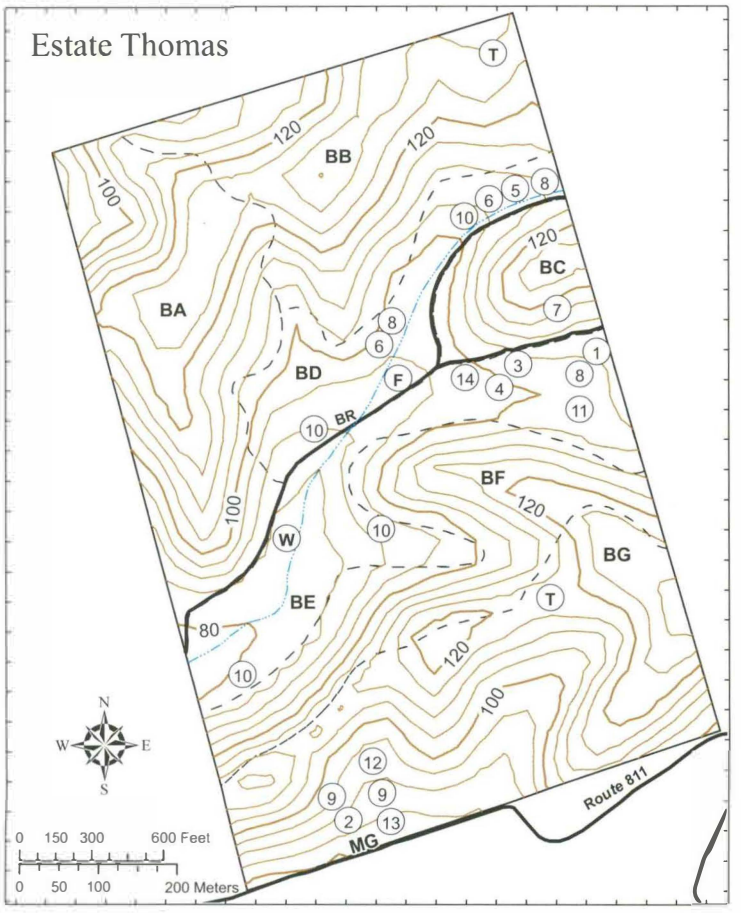
Arawak gravelly loam, a major soil series, occurs on four different slopes at Estate Thomas: C is 5 to 12 percent, D is 12 to 20 percent, E is 20 to 40 percent, and F is 40 to 70 percent (fig. 2). Areas with these different slopes encompass about 12, 24, 29, and 35 percent of Estate Thomas, respectively.

In the soil survey of the Virgin Islands, the Arawak series consists of shallow, well-drained soils situated on steep to very steep slopes and summits in the limestone hills (Davis 2002). They formed in material weathered from calcareous marine sediments. Typically these soils have a very dark, grayish-brown gravelly loam surface layer 15 cm thick. The subsoil, from 15 to 28 cm, is very dark grayish-brown very gravelly loam, and from 28 to 35 cm is pale brown very gravelly loam. Partially weathered limestone and marl is at a depth of 35 cm.

Earlier Puerto Rican literature refers to the Arawak series of soils as Aguilita gravelly clay loam, Sion clay loam with slopes of 0 to 5 percent, and Sion clay loam with slopes of 5 to 12 percent (McKinzie and others 1965, Rivera and others 1970). Later, soil scientists reclassified the Aguilita and Sion series as typic calciustolls (Lugo-Lopez and Rivera 1980). A 1:100,000 map showed that the soils in the central drainage of Estate Thomas were prime farmland (Soil Conservation Service 1963).

## *Physiography*

Hills extend along the north coast of St. Croix, rising to 355 m at Mt. Eagle. The generally low elevations present little obstruction for the trade winds that pass over the island with little cooling or precipitation. The southwestern two-thirds of the island is relatively flat. Estate Thomas, along the southern edge of the hills, is < 2 km from the Caribbean Sea and < 3 km from Christiansted. The Estate's elevation ranges from 80 m in the southwestern corner to 130 m in the southeastern corner and 135 m in the north central part (fig. 3).




**Legend**

**Sites**

| | |
|---|---|
| 1 | Mahogany - provenance |
| 2 | Mahogany - hybrid |
| 3 | Mahogany - root grafting |
| 4 | Mahogany - plum pudding |
| 5 | Mahogany - adaptability |
| 6 | Mahogany - Pacific Coast |
| 7 | Mahogany - thinned |
| 8 | Cedrela - provenance |
| 9 | Cedrela - Puerto Rico |
| 10 | Teak |
| 11 | Species adaptability |
| 12 | Chittagong and student monitoring plot |
| 13 | Toona |
| 14 | Lignum-vitae |
| F | Foundation |
| T | Proposed lookout towers |
| W | Well |
| MG | Main gate |
| 811 | Route #811 - south of estate |
| BR | Bond Road - middle of estate |
| BA-BG | Research blocks A through G |

Research block boundary

Estate Thomas boundary

Intermittent drainage

Elevation contours (meters)

Roads

Figure 3—Estate Thomas topographic map with location of sites of interest.

A drainage, descending in elevation from 95 to 80 m, runs east to west through the center of the property. As with most drainages in St. Croix, flow is intermittent.

Ridges, slopes, and valleys that differ in soil moisture and depth provide distinct habitats for trees and shrubs. Species composition, tree size, and tree density vary along the elevational gradient from valley bottom to ridgetop, with the largest trees in the valleys and the smallest and most numerous trees on the ridges.

## Climate

### General

The generally warm and moist climate of the West Indies today contrasts with the cool, dry climate of 15,000 to 20,000 years ago when savannas were widespread (Wiley and Vilella 1998). Subsequently, with climate change, the flora and fauna gradually evolved toward their composition at the time of European discovery. The widespread plantation agriculture characteristic of recent human activity has dramatically impacted the island, effectively moving the ecosystems once again toward drier conditions by eroding topsoil and reducing soil water-holding capacity.

St. Croix, in the path of the easterly trades, has a tropical maritime climate (Calvesbert 1970, Colón-Dieppa and others 1991). Easterly waves produce most rainfall from May through November. Tropical storms and hurricanes occasionally develop in easterly waves. Although infrequent, they may cause high winds and heavy rainfall. During the winter months, cold fronts penetrate south from the continent. The degree to which these fronts influence rainfall depends on their intensity and rate of movement into the Caribbean.

Although the Estate has no climatic stations, 30-year rainfall and temperature normals (1971-2000) are available from Christiansted Fort, 4 km to the east, and Bethlehem Upper New Works, 6 km to the southwest (table 1, fig. 1). Christiansted Fort is at sea level, and Bethlehem lies inland at 60 m elevation. The mean of monthly rainfalls and temperatures for both stations helps characterize the climate at Estate Thomas.

### Rainfall

Rainfall on Estate Thomas averages 1060 mm/year, ranging from 44 mm in February to 154 mm in November (Bowden and others 1968; table 1). During the September through November wet season, 42

**Table 1—Monthly rainfall and temperature normals, St. Croix, 1971-2000**

| Factor and location | Months | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sept. | Oct. | Nov. | Dec. | Total |
| | *mm* | | | | | | | | | | | | |
| Rainfall | | | | | | | | | | | | | |
| Bethlehem Upper New Works | 53.6 | 48.0 | 48.3 | 56.1 | 89.9 | 63.2 | 72.6 | 102.4 | 158.0 | 154.9 | 155.5 | 93.5 | 1,095.8 |
| Christiansted Fort | 56.1 | 39.1 | 42.9 | 60.4 | 89.2 | 62.2 | 73.2 | 98.0 | 144.8 | 127.8 | 152.4 | 78.7 | 1,024.9 |
| Mean | 54.9 | 43.6 | 45.6 | 58.3 | 89.6 | 62.7 | 72.9 | 100.2 | 151.4 | 141.4 | 154.0 | 86.1 | 1,060.4 |
| | *°C* | | | | | | | | | | | | |
| Temperature | | | | | | | | | | | | | |
| Bethlehem Upper New Works | 24.6 | 24.4 | 24.7 | 25.6 | 26.7 | 27.5 | 27.7 | 27.6 | 27.2 | 26.9 | 26.0 | 25.0 | 26.2 |
| Christiansted Fort | 25.1 | 25.0 | 25.3 | 25.9 | 26.9 | 27.7 | 27.6 | 27.8 | 27.7 | 27.5 | 26.7 | 25.6 | 26.6 |
| Mean | 24.9 | 24.7 | 25.0 | 25.8 | 26.8 | 27.6 | 27.7 | 27.7 | 27.4 | 27.2 | 26.4 | 25.3 | 26.4 |

Source: Southeast Regional Climate Center, South Carolina Department of Natural Resources, Columbia, SC.
Elevations: Bethlehem, 60 m; Christiansted, 1 m.

percent of the total annual rainfall occurs. Rainfall during the dry period from January through April is only 19 percent of the total.

The Southeast Regional Climate Center records show that monthly rainfall has varied considerably during the past 30 years. The lowest and highest monthly rainfalls at Christiansted Fort were 3 mm in February 1983 and 560 mm in September 1979. Comparable records for Bethlehem Upper New Works were 1 mm in April 1997 and 503 mm in September 1979.

Annual rainfall varies considerably on St. Croix (Bowden and others 1968). Based on long-term records through the mid-1960s, Christiansted Fort received at least 500 mm/year, and in 50 percent of the years, at least 1015 mm. Moreover, in about 10 percent of the years, it received 1500 mm or more. Annual rainfall for Sion Farm follows a similar pattern: at least 560 mm in any year, 950 mm or more during one-half of the years, and 1230 mm or more in about 10 percent of the years (Bowden and others 1968).

Exceptionally wet and dry periods occur irregularly on St. Croix (Colón-Dieppa and others 1991, appendix A). Tropical storms or hurricanes flooded parts of St. Croix during 1924, 1928, 1956, 1974, 1977, and 1979. Before 1900, severe droughts were experienced in the spring and summer of 1733, from 1789 to 1791, and during several years in the first half of the 19th century (Dookhan 1974). The worst period for sugar, in part due to drought, was from 1820 to 1840 (Lewisohn 1970). "No rain fell for nine months in 1842, drinking water was in short supply; cattle died by the hundreds and the cane fields turned brown. When the rains came there followed an epidemic of dysentery and measles" (Lewisohn 1970, page 237). The 19th century experienced "regular and constantly occurring drought," which aggravated the "ill effects of the impoverished system of culture" (Dookhan 1974, page 84). During the 20th century, moderate droughts were recorded throughout the island in 1938-42, 1945-48, and 1959, and severe droughts in 1957, 1964, and 1967-68 (Colón-Dieppa and others 1991), and again in 1995. Droughts reduce both plant growth and crop production.

## Temperature

In the Virgin Islands, the range between coolest and warmest mean monthly temperatures is very small (Calvesbert 1970). Mean monthly normal temperatures range from 24.7 °C in February to 27.7 °C in July and August. Mean monthly temperatures have also varied during the past 30 years. The lowest mean monthly temperature for Christiansted Fort was 23.8 °C in February 1976 and the highest 29.0 °C in September 1987. Comparable records for Bethlehem Upper New Works were 23.3 °C in March 1976 and 28.9 °C in June 1998.

## Relative Humidity, Evaporation, and Wind

The relative humidity at Henry E. Rohlsen Field on St. Croix (16 m in elevation) averages near 80 percent for the year, ranging from approximately 85 percent during the night to 70 percent in the mid-afternoon (Calvesbert 1970). During the year, changes in relative humidity are opposite those of temperature, with the highest values being recorded during the winter months and the lowest during the summer months.

The trade winds blow steadily from an easterly direction during virtually the entire year (Calvesbert 1970). The prevailing wind direction recorded at Henry E. Rohlsen Field is east-northeast from November through March and again during July and August; during the remaining months winds blow from the east-southeast. The highest mean maximum wind speed, 26 km/hour, occurs in July and the lowest, 18 km/hour, during October or November. The annual evaporation recorded at Anna's Hope Agricultural Station was nearly 1850 mm/year.

## Hurricanes

Twenty hurricanes passed over or near St. Croix before 1900 (in 1695, 1707, 1714, 1729, 1733, 1742, 1748, 1772, 1785, 1793, 1819, 1825, 1830, 1837, 1866, 1867, 1871 (two events), 1876, and 1899). The most destructive storms were probably those in 1695, 1772, 1785, 1819, 1837, 1867, and 1899 (Dookhan 1974, Lawaetz 1991). Nine hurricanes passed over or very near St. Croix during the 20th century, including unnamed hurricanes in 1916, 1924, and 1928. More recent named hurricanes were David in 1979, Hugo in 1989 (Colón-Dieppa and others 1991), Marilyn in

1995, Hortense in 1996, Georges in 1998, and Lenny in 1999. Some of these are more famous (or infamous) than others. Alexander Hamilton described the 1772 storm as the "most dreadful hurricane that memory or any records whatsoever can trace" (Lewisohn 1970, page 158). The 1819 hurricane purportedly had "the long term effect of convincing many islanders that the future of plantation agriculture was bleak" (Dookhan 1974, page 84). The year 1867 stood out in memory because a few days after a major hurricane, a 7.5 magnitude earthquake caused a tidal wave that deposited the Civil War vessel *Monongahela* upright on Strand Street in Fredericksted (Lewisohn 1970). The 1899 hurricane destroyed numerous sugar factories on the island (Lawaetz 1991), and the 1916 event was labeled as "one of the worst hurricanes experienced during Danish times" (Lewisohn 1970, page 356). After the 1928 hurricane, "scarcely anyone had a rooftop left and the mangle of debris and mud was unimaginable" (Lewisohn 1970, page 371). Moreover, the 135-year-old inter-island schooner *Vigilant*, used for postal and passenger services, was sunk for the third and last time during the hurricane, which was considered by many to be the worst in the history of the Virgin Islands.

Although historically infrequent, the high winds and heavy rainfalls associated with hurricanes severely damage infrastructure and vegetation and often cause fatalities. During the 61-year gap between 1928 and 1989, residents "took it for granted that St. Croix would not experience a heavy one" (Lawaetz 1991, page 442). However, in 1989, Hurricane Hugo destroyed 65 percent of the island's buildings, leaving about 20,000 people homeless (Schuck-Kolben and Kaufman 1991). Hugo did enormous damage because many of the new homes were not as well built as older structures (Lawaetz 1991). Hugo also caused tidal flooding in coastal areas. Beach erosion, however, was less than expected, and reef damage was patchy, with reefs on the south side of Buck Island suffering the most severe damage observed around St. Croix (Hubbard and others 1991).

Damage caused by Hurricane Hugo was related to gust speed at several sites in Puerto Rico and the Virgin Islands, including St. Croix, where maximum gusts were estimated at 300 km/hour (Francis and Gillespie 1993). Damage to ornamental and shade trees began at speeds of 60 km/hour and increased rapidly to about 130 km/hour but did not worsen at higher speeds. Although damage to Estate Thomas was not assessed immediately after the storm, subsequent visits showed major impacts to teak and mahogany plantings and to the surrounding forest. Dicotyledonous trees suffered more than palms.

## Flora

St. Croix has two ecological life zones (Ewel and Whitmore 1973, Holdridge 1967): subtropical moist forest, which is confined to the northwestern one-sixth of the island, and subtropical dry forest where Estate Thomas is located. Indian activities before Columbus had little influence on the vegetation of St. Croix. Historical records provide no information on the original composition of the forest except for the statement that "this land had to be cleared of bush and forest before it could be planted; pockwood [*Guaiacum officinale*] was sufficiently in demand in Denmark to furnish a profitable ballast for returning ships" (Bevan 1940, page 8). It is only possible to conjecture about the original flora of St. Croix; however, with the island's low elevation and dry conditions, it would most likely not have been spectacular (Fosberg 1974). In 1629, however, French sailors found St. Croix "very beautiful . . . with beautiful rivers" (Lewisohn 1970, page 44), suggesting that the original forest cover, probably in the northwest, provided more humid conditions than are evident today. At least one plantation owner who lived on St. Croix from 1739 through 1752 described most of the island as heavy jungle with some large trees used for construction of houses and windmills, both locally and on other Caribbean islands (Haagensen 1995). He commented that "the amount of valuable timber and rare trees that were destroyed by fire and by the ax when the Danes initially started to develop the island is unbelievable" (Haagensen 1995, page 3). Yet, despite the rampant burning, two species were carefully spared, namely "fustick" (*Chlorophora tinctoria*) and pockwood, both of which were considered "practically as good as money in the bank" (Haagensen 1995, page 6).

Of the nearly 900 native seed plants initially recorded in the local flora of the Virgin Islands, only four were purportedly endemic to St. Croix (Britton 1918, Britton and Wilson 1923-26). With additional botanical explorations, virtually all of the endemic tree species reported years ago have been

found again, and most of those previously considered endemics have been found on other islands (Little and Woodbury 1980). Today, six tree species are known exclusively from St. Croix and other U.S. and British Virgin Islands and Puerto Rico's offshore islands, Vieques and Culebra: *Chrysophyllum pauciflorum*, *Croton rigidus*, *Erythrina eggersii*, *Eugenia sessiliflora*, *Maytenus cymosa*, and *Pictetia aculeata*. Only one tree species, *Malphigia pallens*, is found exclusively in St. Croix, including Buck Island. Two other tree species, *Buxus vahlii*, in the hills south of Christiansted on St. Croix, and *Cordia rickseckeri*, are reported for St. Croix and Puerto Rico (Breckon and Kolterman 1993, see endnotes; Little and Woodbury 1980). Taxonomists have described and illustrated all of the trees on the Virgin Islands, including rare and endemic native and common exotic species (Little and Wadsworth 1964, Little and others 1974). Moreover, recent comprehensive taxonomical references contain descriptions of the flora of Puerto Rico, adjacent islands, and the West Indies, including St. Croix (Howard 1979, 1988-89; Liogier 1985-97; Liogier and Martorell 1982).

Plantation agriculture involved the widespread use of fire, the diversion of water for irrigation, and the introduction of livestock and exotic plants. These activities caused soil erosion and changes in vegetation (Fosberg 1974). With drier conditions, moisture-loving plants, originally restricted to humid sites, were reduced in number or exterminated; in contrast, xeric species extended their ranges. Fruit trees and ornamentals in local woodlands are remnants of earlier agricultural activities and scattered settlements (Borie 1979, see endnotes).

Neither small-leaf mahogany (*Swietenia mahagoni*) nor big-leaf mahogany (*S. macrophylla*) was present in the island's native forests; the first was introduced about 1770, probably from Jamaica, and the second in 1907 (Francis and Alemañy 2003, Nobles 1960). Teak (*Tectona grandis*), the third species of major commercial value, was introduced to St. Croix in 1954 (Nobles 1960). In 1986, many of the small-leaf mahoganies along Mahogany Road, assumed to have been planted 200 years earlier, still survived. Moreover, they averaged about 1.25 m in diameter at 1.4 m above the ground (d.b.h.), having grown at an estimated rate of 0.63 cm/year (Francis 1995, 2000b; Weaver and Francis 1988).

During the 1700s, or possibly earlier, planters cleared extensive areas of native vegetation on Estate Thomas to cultivate sugar cane. When agriculture and grazing on the hills ceased in 1928, much of the Estate regenerated in small-leaf mahogany (Weaver and Francis 1988). The seed apparently blew in from the upper slopes of Bellevue Estate to the east (Ward and others 2002). Agriculture continued in the central drainage until 1954 when tree planting started, mainly of small-leaf mahogany but also of other species including teak. By 1960, the estates Bellevue, Little Princess, and Thomas together contained 100 ha of small-leaf mahogany, the largest mahogany stand on the island (Nobles 1960). Earlier measurements showed that some of the densest parts of this stand, virtually all small-leaf mahogany, had basal areas of 45 $m^2$/ha (Wadsworth 1947). Hurricane Hugo of 1989 and subsequent storms heavily damaged trees in the drainage. Today, the valley is covered with a dense growth of secondary tree species and shrubs, notably two exotics: tan tan (*Leucaena leucocephala*) and the spiny sweet-lime (*Triphasia trifoliata*) (Ward and others 2002).

During a 1997 survey, all trees ≥ 5 cm in d.b.h. at Estate Thomas were tallied along with minor vegetation on 55 randomly distributed plots with a 10-m radius (about 0.03 ha in area) (Francis 2002; table 2). The inventory showed:

- 110 species of herbs, ferns, vines, shrubs, and trees; 83 percent woody and 14 percent exotic
- An average of 24 species per plot
- 2,885 trees averaging about 10 cm in d.b.h. and ranging from 5 to about 60 cm in d.b.h.
- A mean density 1,672 trees/ha and mean basal area of 17.6 $m^2$/ha
- A mean canopy height of about 8 m with the tallest trees per plot between 4 and 18 m
- Small-leaf mahogany accounted for one-half of all trees and two-thirds of the total basal area
- A species-area curve indicating successful sampling of most of the Estate's plant species

In addition to the species recorded on the plots, the trees *Acacia farnesiana*, *S. humilis*, and *Tectona grandis*, and the vine *Ipomoea hederifolia*, were observed in the former plantation within the drainage. Deer consume the fruits, pods, or leaves of nine of the recorded species, six of them trees (Seaman 1966;

**Table 2—Plant species recorded at Estate Thomas**[a]

| Family and species | Life form[b] | Range[c] | Medicinal use[d] | Poisonous[e] |
|---|---|---|---|---|
| Acanthaceae | | | | |
| *Oplonia spinosa* (Jacq.) Raf. | S | N | | |
| Agavaceae | | | | |
| *Agave missionum* Trel. | S | N | | |
| Anacardiaceae | | | | |
| *Comocladia dodonaea* (L.) Urban | S | N | | Le, Sa |
| Annonaceae | | | | |
| *Annona muricata* L.[f] | T | N | Fr, Le | |
| *A. squamosa* L.[f] | T | N | | |
| Apocynaceae | | | | |
| *Rauvolfia nitida* Jacq. | T | N | | Sa |
| Asclepiadaceae | | | | |
| *Metastelma parviflorum* (Sw.) R. Br. ex JA Schultes | V | N | | |
| Bignoniaceae | | | | |
| *Distictis lactiflora* (Vahl) DC. | V | N | | |
| *Macfadyena unguis-cati* (L.) A. Gentry | V | N | | |
| *Tabebuia heterophylla* (DC.) Britton[g] | T | N | | |
| *Tecoma stans* (L.) Jess. ex Kunth[g] | S | N | Le | |
| Bombacaceae | | | | |
| *Ceiba pentandra* (L.) Gaertn.[g] | T | N | | |
| Boraginaceae | | | | |
| *Bourreria succulenta* Jacq. | T | N | | |
| *Cordia alba* (Jacq.) Roem & Schult. | T | N | | |
| *C. collococca* L. | T | N | | |
| *C. laevigata* Lam. | T | N | | |
| *C. polycephala* (Lam.) I.M. Johnst. | S | N | | |
| *C. stenophylla* Alain | S | N | | |
| *Tournefortia volubilis* L. | S | N | | |
| Bromeliaceae | | | | |
| *Tillandsia utriculata* L. | H | N | | |
| Burseraceae | | | | |
| *Bursera simaruba* (L.) Sarg.[g] | T | N | Ba, Le, Sa, Tw | |
| Canellaceae | | | | |
| *Canela winterana* (L.) Gaertn.[g] | T | N | Ba, Le | |
| Capparaceae | | | | |
| *Capparis baducca* L. | T | N | | |
| *C. cyanophallophora* L.[g] | T | N | | |
| *C. flexuosa* (L.) L. | V | N | | |
| *C. indica* (L.) Druce | T | N | | |
| Cariaceae | | | | |
| *Carica papaya* L. | S | E | | |
| Celastraceae | | | | |
| *Crossopetalum rhacoma* Crantz | S | N | | |
| *Maytenus cymosa* Krug & Urban[h] | T | N | | |
| *M. elliptica (Lam.)* Krug & Urban | T | N | | |
| Commelinaceae | | | | |
| *Commelina diffusa* Burm. | H | N | | |

*continued*

**Table 2—Plant species recorded at Estate Thomas[a] (continued)**

| Family and species | Life form[b] | Range[c] | Medicinal use[d] | Poisonous[e] |
|---|---|---|---|---|
| Compositae | | | | |
| *Pluchea odorata* (L.) Cass. | H | N | | |
| *P. symphytifolia* (Miller) Gillis | S | N | | |
| *Synadrella nodiflora* (L.) Gaertn. | H | N | | |
| *Vernonia albicaulis* Pers. | V | N | | |
| Convolvulaceae | | | | |
| *Ipomoea hederifolia* L. | V | N | | |
| *I. repanda* Jacq. | V | N | | |
| *Jacquemontia pentantha* (Jacq.) Don | V | N | | |
| Cyperaceae | | | | |
| *Scleria lithosperma* (L.) Sw. | G | N | | |
| Erythroxylaceae | | | | |
| *Erythroxylum brevipes* DC. | S | N | | |
| Euphorbiaceae | | | | |
| *Argythamnia candicans* Sw. | S | N | | |
| *Croton astriotes* Dryand. | S | N | | Le, Se, St |
| *C. betulinus* Vahl | S | N | | Le, Se, St |
| *C. rigidus* (Muell. Arg.) Britton | S | N | | |
| *Gymnanthes lucida* Sw. | T | N | | |
| *Margaritaria nobilis* L. | T | N | | |
| *Securinega acidoton* (L.) Fawc. & Rendle | S | N | | |
| *Tragia volubilis* L. | V | N | Lv | |
| Flacourtiaceae | | | | |
| *Casearia guianensis* (Aubl.) Urban | T | N | | |
| Gramineae | | | | |
| *Lasiacis divaricata* (L.) Hitchc. | G | N | | |
| *Panicum maximum* Jacq.[f] | G | E | | |
| Leguminosae (Mimosoideae) | | | | |
| *Acacia farnesiana* (L.) Willd.[g] | T | N | | |
| *A. macrantha (L.)* Willd.[f] | T | N | | |
| *Albizia lebbeck (L.)* Benth.[f] | T | E | Ba, Le | |
| *Leucaena leucocephala* (Lam.) DeWit[f] | T | E | | Le, Se |
| *Pithecellobium unguis-cati* (L.) Benth.[g] | S | N | | |
| Leguminosae (Caesalpinaceae) | | | | |
| *Haematoxylum campechianum* L. | T | E | | |
| *Tamarindus indica* L.[f] | T | E | | |
| Leguminosae (Fabaceae) | | | | |
| *Centrosema virginianum* (L.) Benth. | V | N | | |
| *Cracca caribaea* (Jacq.) Benth. | S | N | | |
| *Galactia striata* (Jacq.) Urban | V | N | | |
| *Rhynchosia reticulata* (Sw.) DC. | V | N | | |
| Lilaceae | | | | |
| *Sansevieria hyacinthoides* (L.) Druce | H | E | | |
| Malphigiaceae | | | | |
| *Bunchosia glandulosa* (Cav.) L.C. Rich | T | N | | |
| *Heteropteris purpurea* (L.) Kunth | V | N | | |
| *Stigmaphyllon emarginatum* (Cav.) A. Juss. | V | N | | |

*continued*

**Table 2—Plant species recorded at Estate Thomas[a] (continued)**

| Family and species | Life form[b] | Range[c] | Medicinal use[d] | Poisonous[e] |
|---|---|---|---|---|
| Meliaceae | | | | |
| *Cedrela odorata* L. | T | N | | |
| *Chukrasia sp.* | T | E | | |
| *Swietenia humilis* Zucc. | T | E | | |
| *S. macrophylla* G. King | T | E | | |
| *S. mahagoni* (L.) Jacq. | T | E | | |
| *S. macrophylla x mahagoni (hybrid)* | T | E | | |
| *Trichilia hirta* L. | T | N | | |
| Moraceae | | | | |
| *Ficus citrifolia* Miller | T | N | | |
| Myrtaceae | | | | |
| *Calyptranthes pallens* Griseb. | T | N | | |
| *Eugenia foetida* Pers. | T | N | | |
| *E. maleolens* Pers. | T | N | | |
| *E. monticola* (Sw.) DC. | T | N | | |
| *E. procera* (Sw.) Poiret | T | N | | |
| *E. sintenisii* Kiaersk. | S | N | | |
| Nyctaginaceae | | | | |
| *Guapira fragrans* (Dum.-Cours) Little | T | N | | |
| *Pisonia aculeata* L. | V | N | | |
| Oleaceae | | | | |
| *Chionanthus compacta* Sw. | T | N | | |
| *Jasminum fluminense* Vell. | V | E | | |
| Palmae | | | | |
| *Roystonea borinquena* O.F. Cook[g] | T | N | | |
| Passifloraceae | | | | |
| *Passiflora laurifolia* L. | V | N | Fr, Le, St | |
| *P. runra* L. | V | N | | |
| *P. suberosa* L. | V | N | | |
| Phytolacaceae | | | | |
| *Trichostigma octandrum* (L.) H. Walt. | V | N | | |
| Polygalaceae | | | | |
| *Securidaca virgata* Sw. | V | N | | |
| Polygonaceae | | | | |
| *Coccoloba diversifolia* Jacq.[g] | T | N | | |
| Rhamnaceae | | | | |
| *Colubrina arborescens* (Mill.) Sarg. | T | N | | |
| *C. elliptica* (Sw.) Briz. & Stern | T | N | | |
| *Gouania lupuloides* (L.) Vent. | V | N | St | |
| *Krugiodendron ferreum* (Vahl) Urban[g] | T | N | | |
| Rubiaceae | | | | |
| *Exostema caribaeum* (Jacq.) Roemer & Schultes[g] | T | N | | |
| *Guettarda scabra* (L.) Vent. | T | N | | |
| *Psychotria nervosa* Sw. | S | N | | |
| *Randia aculeata* L.[g] | S | N | | |

*continued*

**Table 2—Plant species recorded at Estate Thomas[a] (continued)**

| Family and species | Life form[b] | Range[c] | Medicinal use[d] | Poisonous[e] |
|---|---|---|---|---|
| Rutaceae | | | | |
| *Amyris elemifera* L. | S | N | | |
| *Murraya paniculata* (L.) Jack | S | E | | |
| *Triphasia trifolia* (Burm. f.) P. Wilson | S | E | | |
| Sapindaceae | | | | |
| *Melicoccus bijugatus* Jacq.[f] | T | E | Fr, Le, St | |
| *Serjania polyphylla* (L.) Radlk. | V | N | | |
| Sapotaceae | | | | |
| *Bumelia obovata* (Lam.) A. DC. | T | N | | |
| *Chrysophyllum pauciflorum* Lam[g] | T | N | | |
| *Sideroxylon foetidissimum* Jacq. | T | N | | |
| *S. salicifolium* (L.) Lam. | T | N | | |
| *Manilkara zapota* (L.) R. van Royen[g] | T | E | | |
| Solanaceae | | | | |
| *Solanum polygamum* Vahl | S | N | | |
| Sterculiaceae | | | | |
| *Melochia nodiflora* Sw. | S | N | | |
| Tiliaceae | | | | |
| *Corchorus hirtus* L.[f] | H | N | | |
| Verbenaceae | | | | |
| *Citharexylum fruticosum* L.[g] | T | N | | |
| *Lantana camara var. aculeata* (L.) Mold. | S | N | Le, St | Fr, Le |
| *L. involucrata* L. | S | N | | Le |
| *L. urticifolia* Miller | S | N | | |
| *Priva lappulacea* (L.) Pers. | H | N | | |
| *Tectona grandis* L. f. | T | E | | |
| Vitaceae | | | | |
| *Cissus verticillata* (L.) Nicolson & Jarvis | V | N | | |
| Zygophyllaceae | | | | |
| *Guaicum officinale* L.[g] | T | N | Ba, Fl, Le, Re, Wo | |

[a] Francis 2002; also, field observations and unpublished surveys.
[b] Life form: G = grass; H = herb; S = shrub; T = tree; and V = vine.
[c] Range: E = exotic; N = native.
[d] Medicinal use: Ba = bark; Fr = fruit; Fl = flower; Le = leaf; Lv = leafy vine; Re = resin; Sa = sap; St = stem; Tw = twig; and Wo = wood (Thomas and others 1997).
[e] Poisonous: Fr = fruit; Le = leaf; Sa = sap; Se = seed; St = stem (Oakes and Butcher 1962, Nellis 1997).
[f] Eaten by deer (Seaman 1989).
[g] Native tree recommended for landscaping (Jones 1995).
[h] Endangered on St. Thomas and St. John (Gibney and others 1991, see endnotes).

table 2). Also, 17 of the recorded native tree species are recommended for landscaping on St. Croix (Jones 1995; table 2).

Some idea of the original vegetation on St. Croix is available from earlier descriptions of the British Virgin Islands (Beard 1949). During the 1940s, the existing dry scrub woodlands were considered probable remnants of a two-storied forest with a canopy composed of numerous deciduous trees and an understory dominated by evergreen shrubs (Beard 1949). Among the native species were the canopy trees *Bursera simaruba* and *Tabebuia pallida* (syn. *T. heterophylla*). Among the understory shrubs or trees were *A. macrantha*, *Guettarda scabra*, and

*Pithecellobium unguis-cati*. Seasonal deciduous forest originally covered much of Jost van Dyke, but the island was later cleared for sugar cane and grazing (Little 1969). In 1967, the surviving native tree species included *A. macrantha*, *Bunchosia glandulosa*, *Bursera simaruba*, and *T. pallida*. Among the shrubs observed were *Amyris elemifera*, *Bourreria succulenta*, *Capparis flexuosa*, *Comocladia dodonaea*, *Eugenia monticola*, *Exostema caribaeum*, *Krugiodendron ferreum*, and *Randia aculeata*—species also found at Estate Thomas (Francis 2002).

A late 1960s description of the forests on the three main Virgin Islands listed species typical in the dry forest type: *A. elemifera*, *Capparis cyanophallophora*, *Canela winterana*, *Citharexylum fruticosum*, *Crossopetallum rhacoma*, *E. caribaeum*, *K. ferreum*, and *R. aculeata*, all found at Estate Thomas (Francis 2002, Zube 1968). According to the mid-1970s classification of the forest types for St. Croix based on moisture regimes (Forman 1974), Estate Thomas would likely have been classified as deciduous forest. Some of the dominant native tree species mentioned for the deciduous forest were *Bursera simaruba*, *Tecoma stans*, *Capparis flexuosa*, *C. indica*, *Cordia dentata* (syn. *C. alba*), and *T. pallida*, again, all species at Estate Thomas (Francis 2002).

A preliminary survey on St. John in the early 1980s revealed 10 vegetation types (Woodbury and Weaver 1987). Among the types most similar to those found on Estate Thomas were gallery moist forest (common in the drainages) and an upland variation of dry evergreen woodland with deciduous species (common on slopes and hilltops). At the moment, however, deciduous exotics dominate the forest at Estate Thomas: small-leaf mahogany in the hills and tan tan in the drainage. Both areas are recovering from the severe impacts of Hurricane Hugo and subsequent storms.

Many islanders, particularly in the past, used the local flora as remedies for illness, parasites, or evil spirits. West Indian "weed women" on St. Croix inherited generations of lore on the curative powers of certain plants (Lewisohn 1970, Oakes and Morris 1958). As a group, these respected older women used at least 58 plant species in 30 different families, alone or in combination, as alternatives to the common practices of the time—bleeding, sweating, and purging. Depending on the illness and species, herbal healers used the bark, flowers, fruits, leaves, leafy vines, resin, sap, stems, twigs, and even wood, alone or with other plants, either externally or decocted and taken internally (Thomas and others 1997). Purported remedies were various: sometimes the herbs were used as a bath, culinary spice, or hemostat to stop bleeding of wounds, or as a tonic for colds, fever, headaches, diarrhea, flu, rheumatism, appetite stimulant, antiseptic, or diuretic. Today, despite rapid change and modernization, an interest in the traditional use of medicinal plants persists. A recently published list of medicinal plants for the Virgin Islands includes 35 herbaceous species, 11 trees, 12 shrubs, and 10 vines (Thomas and others 1997). Eight of the trees, one shrub, and three of the vines listed have been identified at Estate Thomas (Francis 2002; table 2). Numerous plants reputed to have medicinal uses or poisonous effects were also reported for the flora of St. John, Virgin Islands (Woodbury and Weaver 1987).

Six species on the Estate apparently have poisonous effects on humans or animals (Oakes and Butcher 1962; table 2). One plant causes skin irritation when touched by humans, and another causes horses and mules to lose their hair; still others cause paralysis and even death if consumed in quantity by certain animals. However, the taste of most poisonous plants is so unpleasant that they are rarely eaten.

Estate Thomas has no known threatened or endangered plants protected by the U.S. Endangered Species Act of 1973 (Gibney and others 1991, see endnotes; Silander 1992). However, two species listed in the Virgin Islands Endangered and Indigenous Species Act of 1990 (Act No. 5665) grow on Estate Thomas: a small, rare tree in the Celastraceae family (*Maytenus cymosa*) (table 2) and lignum-vitae (*Guaiacum officinale*). Lignum-vitae may have occurred naturally on the Estate's upper slopes and ridges, but trees present on the Estate today were planted in 1969. Previously, lignum-vitae was in high demand for its dense, self-lubricating wood (Thomas and others 1997). Currently, horticulturists value the species for its blue flowers and stately crown.

## *Fauna*

A preliminary survey of wildlife at Estate Thomas in the late 1990s identified 16 species of birds, 2 lizards, and 2 bats (table 3). Several of the species reported for terrestrial habitats elsewhere on St. Croix could occur on the Estate as residents, migrants, or occasional visitors. Additional surveys are needed.

**Table 3—Mammal, bird, and reptile species recorded at Estate Thomas[a]**

| Group and species (common name) |
|---|
| **Mammals** |
| *Odocoileus virginiana* (white-tailed deer) |
| *Artibeus jamaicensis* (Jamaican fruit-eating bat) |
| *Molossus molossus* (velvety free-tailed bat) |
| **Birds** |
| *Coccyzus minor* (mangrove cuckoo)[b] |
| *Coereba faveola* (bananaquit)[b] |
| *Columba squamosa* (scaly-naped pigeon)[b] |
| *Columbina passerina* (common ground-dove)[b] |
| *Crotophaga ani* (smooth-billed ani)[b] |
| *Dendroica petechia* (yellow warbler) |
| *Elaenia martinica* (Caribbean elaenia)[b] |
| *Eulampis holosericeus* (green-throated Carib)[b] |
| *Loxigilla noctis* (Lesser Antillean bullfinch)[c] |
| *Margarops fuscatus* (pearly-eyed thrasher)[b] |
| *Mimus polyglottos* (Northern mockingbird)[b] |
| *Orthorynchus cristatus* (Antillean crested hummingbird)[b] |
| *Tiaris bicolor* (black-faced grassquit)[b] |
| *Tyrannus dominicensis* (grey kingbird)[b] |
| *Vireo altiloquus* (black-whiskered vireo)[b] |
| *Zenaida aurita* (zenaida dove)[b] |
| **Reptiles** |
| *Anolis acutus* (St. Croix tree lizard) |
| *Sphaerodactylus macrolepis* (wood slave) |

[a] García and García 1997, see endnotes.
[b] Bird species attracted by residential tree plantings (Wadsworth 2002).
[c] Species is rare and local on St. Croix and also attracted by residentialtree plantings (Source: Personal communication. 2005. Douglas B. McNair, Endangered Species Biologist, Division of Fish and Wildlife, Department of Planning and Natural Resources, 45 Mars Hill, Frederiksted, St. Croix, VI 00804.

### Mammals

St. Croix has very few native mammals because of its distance from the centers of origin in North and South America (McManus 1974). Historically, species of the rodent genera *Capromys*, *Isolobodon*, and *Dasyprocta* were exterminated, probably during the destruction of the island's original forests (Beatty 1944). The only indigenous mammals are four species of bats (Nellis and Everhard 1983, Schmidt 1928, Seaman 1961). Two occur on the Estate: the Jamaican fruit-eating bat (*Artibeus jamaicensis*) and the velvety free-tailed bat (*Molossus major*) (table 3). The mongoose (*Herpestus auropunctatus*), introduced in 1884 to control rat damage in sugar cane fields, has been detrimental to ground-nesting birds, snakes, lizards, amphibians, land crabs, sea turtle eggs, and even fawns (Nellis and Everhard 1983, Seaman and Randall 1962, Wolcott 1953, Zube 1968). The mongoose, an omnivorous carnivore, preferentially feeds on small rodents and birds, but when these are depleted turns to lizards and arthropods.

White-tailed deer were introduced, probably in the 1790s, as a game animal. Population estimates during the mid-1970s were about 1,000 animals. Some were recorded on Estate Thomas in the 1960s, and fecal droppings provided evidence of their presence in the late 1990s (table 3). Other common mammals, the black rat (*Rattus rattus frugivorus*) and the house mouse (*Mus musculus*), probably live on the Estate.

### Birds

Sixty-two of the 138 bird species recorded for St. Croix are migrants (Beatty 1930, Leck 1974a). Sixty of these species were seen during visits to the major habitats during the summers of 1970 and 1971. During the rapid bird assessment for the Virgin Islands, 24 species were noted in dry forest, which included semi-deciduous forest in and around Estate Thomas (Rodrigues 2002). Only 16 species, however, were recorded during May 1997 on Estate Thomas (table 3): the Antillean crested hummingbird (*Orthorynchus cristatus*), bananaquit (*Coereba faveola*), black-faced grassquit (*Tiaris bicolor*), black-whiskered vireo (*Vireo altiloquus*), Caribbean elaenia (*Elaenia martinica*), common ground-dove (*Columbina passerina*), green-throated Carib (*Eulampis holosericeus*), grey kingbird (*Tyrannus dominicensis*), Lesser Antillean bullfinch (*Loxigilla*

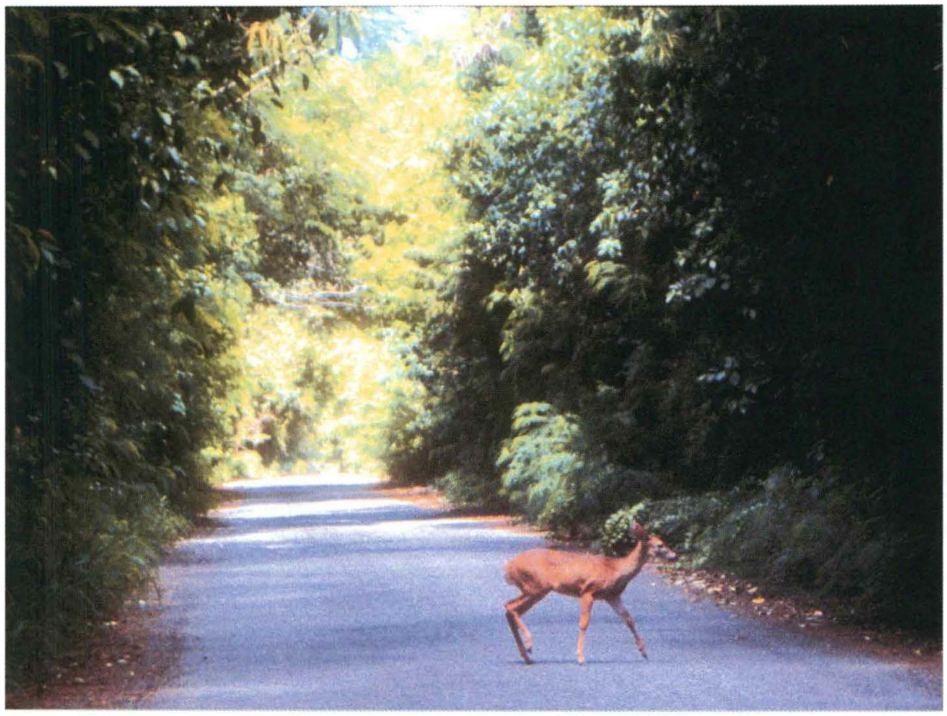


Photo courtesy of Peter L. Weaver.

*White-tailed deer* (Odocoileus virginiana). *Introduced on St. Croix in the 1790s as a game animal, deer today live on Estate Thomas and in other areas such as Creque Dam (shown here).*

*noctis*), mangrove cuckoo (*Coccyzus minor*), pearly-eyed thrasher (*Margarops fuscatus)*, northern mockingbird (*Mimus polyglottos*), scaly-naped pigeon (*Columba squamosa*), smooth-billed ani (*Crotophaga ani*), yellow warbler (*Dendroica petechia*), and the Zenaida dove (*Zenaida aurita*). All of these except the yellow warbler are species that could be attracted to home gardens in urban areas by tree planting (Wadsworth 2002). The Lesser Antillean bullfinch, not recorded in dry forest during the rapid assessment, is rare and local on St. Croix (table 3). Moreover, new surveys on Estate Thomas would probably detect additional species not observed during the brief survey (table 3). Estate Thomas is, therefore, a central refuge for the island's most visible avifauna, including a species not common elsewhere on the island.

Road transects before and after Hurricane Hugo provided estimates of the storm's impact on St. Croix bird populations (Wauer and Wunderle 1992). The surveys showed 33 species before and after; however, the average number of individuals had declined at the sampling sites. Among the terrestrial bird species, those that consume nectar, fruit, or seeds, or combinations of these, suffered proportionately greater losses than either birds of prey or species feeding on insects. The pattern suggests greater stress after rather than during the storm. Hurricanes cause the temporary loss of semi-evergreen and deciduous forest resources—destroying foliage, flowers, fruits, and seeds—and recovery requires several months or perhaps years. Although the impact on resident bird species at Estate Thomas may have been substantial, the Estate's rugged terrain probably allowed patches of forest to survive virtually intact.

## Reptiles and Amphibians

Eighteen species of reptiles and amphibians, excluding sea turtles, occur on St. Croix, and two other species are considered doubtful (MacLean 1982, McManus 1974, Schmidt 1928, Seaman 1961). Confirmed reptiles include a "ground worm," four geckos, an iguana, three anoles, two ground lizards, and a blind snake; of questionable occurrence are two other species of snakes. Amphibians include two toads, a water frog, and three tree frogs. Three lizards and one snake are endemic (MacLean 1982). The snake, the St. Croix racer (*Alsophis sanctcrucis*), is apparently extinct because of mongoose predation. The mongoose eliminated the St. Croix ground lizard from St. Croix, but the lizard survives on offshore islands. Recorded so far on Estate Thomas are the tree lizard (*Anolis acutus*) and a gecko (*Sphaerodactylus macrolepis*) called the cotton ginner (table 3).

### Butterflies

Eighteen species of butterflies have been recorded on St. Croix (Comstock 1944, Leck 1974b; table 4). *Leptotes* sp. has not been sighted since the 1940s, and *Dryas julia*, noted during the 1970s, is apparently an accidental observation or vagrant. No one has studied butterflies at Estate Thomas. Butterfly species most commonly occur in their preferred habitats (open areas, mixed cover, or forested sites) and during a particular season (dry, wet, or perhaps both). Estate Thomas is mostly forested but does contain some small open areas, mainly along the dirt road. Although virtually any of the 18 species could be seen at the Estate, the 10 species listed for mixed or wooded cover during any season would be most likely.

**Table 4—Butterfly species that may be seen at Estate Thomas[a]**

| Family and species | Preferred habitat[b] | Season[c] | Abundance[d] |
|---|---|---|---|
| Danidae | | | |
| *Danaus plexippus* | O | D | C |
| Lycaenidae | | | |
| *Hemiargus ceraunus* | O | B | C |
| *Leptotes cassius* | NA | NA | NA, E |
| *Strymon bubastus* | O | B | C |
| *S. simaethis* | F | D | U |
| Nymphalidae | | | |
| *Agraulis vanillae* | M | B | C |
| *Anartia jatrophae* | O | D | U |
| *Anea troglodyta* | O | D | U |
| *Biblis hyperia* | F | W | C |
| *Dyras julia* | M | D | V |
| *Eunica tatila* | F | W | U |
| *Heliconius charithonius* | F | W | C |
| *Metamorpha stelenes* | F | W | C |
| *Precis lavinia* | O | B | A |
| Papilionidae | | | |
| *Papilo polydamas* | M | B | C |
| Pieridae | | | |
| *Ascia monuste* | O | B | A |
| *Eurema daira* | M | W | U |
| *E. lisa* | O | B | A |
| *Phoebis sennae* | M | B | C |

[a] Source: Comstock 1944, Leck 1974b.
[b] Preferred habitat: F = forest or wooded; O = open; M = mixed; NA = not listed.
[c] Season: B = both; D = dry; W = wet; NA = not listed.
[d] Occurrence: A = abundant; C = common; E = possibly extinct; U = uncommon; NA = not listed.

## *Human Settlement*

### Pre-Columbian

Three groups of Native Americans arrived in the Virgin Islands before Columbus. The Ciboneys, coming from Florida, Central America, or South America about 400 to 300 B.C., reached at least as far as Krum Bay in St.Thomas (Dookhan 1974). The Arawaks, traveling from South America around 200 A.D., conquered the Ciboneys and settled throughout the Virgin Islands. Finally, about 1350 to 1400 A.D., the Caribs, followed the Arawaks from South America, conquered them and took over their settlements. Members of these groups had advanced as far as the eastern shores of Puerto Rico before the arrival of Columbus. Evidence of Native American activity on St. Croix may be found on at least 62 sites, many of them coastal (Lawaetz 1991). Salt River and St. George are among the largest and most interesting.

The Ciboneys relied heavily on fish, as did the Arawaks and Caribs, though the latter two groups supplemented their diets from other sources (Dookhan 1974, Hatch 1972). The basic materials used by the Native Americans were stone, shell, bone, and wood. Their subsistence activities were mollusk collecting, fishing, and slash-and-burn agriculture to grow manioc, corn, potatoes, yams, beans, and peppers,

more so for the Arawaks than the Caribs. Destructive storms and droughts made permanent settlements on many islands difficult and no doubt contributed to inter-island movements (Haas 1940).

In November 1493 Columbus discovered and named the Virgin Islands on his second voyage as he sailed northward from Dominica through the Leeward Islands to Puerto Rico and Hispaniola (Lawaetz 1991). While landing at Salt River, his sailors had a violent encounter with the Caribs. Indeed, the report of the incident is dramatic: "The Caribs began shooting at us with their bows in such a manner that, had it not been for the shields, half of us would have been dead or wounded" (Lewisohn 1970, page 5). The subsequent history of the Virgin Islands has been no less interesting: "They have been under seven flags—Spanish, British, Dutch, French, Knights of Malta, Danish, and the U.S.—not to mention the intervals when they were held or used by a motley roster of pirates, private owners, trading companies, and squatters" (Copeland 1976, page 22).

The arrival of Europeans in the West Indies reduced indigenous populations through death or migration. About 1555, the indigenous peoples were apparently discouraged from living in the Virgin Islands by the mandate of Charles V of Spain, who ordered that they should be treated as enemies (Dookhan 1974). By 1672, when the Danes began to colonize the islands, few Native Americans lived there. Because of the local labor shortage for agriculture, planters imported slaves from Africa.

## Settlement and Plantation Agriculture: 1625-1917

About 1625, English and Dutch settlers arrived on St. Croix, the former at an estate near the south coast called Old Pye (near Frederiksted) and the latter at Bassin (today Christiansted). Quarrels over territory, jurisdiction, and authority characterized this period (Cederstrom 1950; Lewisohn 1964, 1970). In the 1630s, French Protestants helped the Dutch with construction and road clearing but soon departed. About 1647, the English forced the Dutch out after a bitter struggle, and in 1650, the Spanish from Puerto Rico drove the English out during a surprise nocturnal raid. Later in 1650, the French ousted the Spanish and settled the island with planters from St. Kitts. At that time, the French planted sugar cane extensively along with indigo and tobacco (Lewisohn 1964). In 1660, the Governor of St. Kitts bought St. Croix and deeded it to the Knights of Malta. In 1665, the French West India Company purchased St. Croix, and in 1672, the French Crown assumed control. During the late 17th century, St. Croix was a pirate rendezvous where public auctions of purloined goods were held (Lewisohn 1970). By 1695, most of the French had departed, and few inhabitants remained on the island.

The first Danish ship sailed for the West Indies from Copenhagen in 1652, and the Danes became seriously involved in the Virgin Islands when they attempted to colonize St. Thomas in the mid-1660s, finally succeeding in 1672 (Dookhan 1974). In 1675, they ventured to nearby St. John, but delayed settlement of that island until 1718. Finally, in 1733, more than a century after settlement of St. Croix by other nations, the Danish West India and Guinea Company purchased St. Croix from the French.

In 1754, the Virgin Islands became a Danish royal colony, and the capital was transferred from Charlotte Amalie, St. Thomas, to Christiansted, St. Croix. In 1800 and again in 1807, as a result of European conflicts, the Danish surrendered the Virgin Islands to the British for brief periods. In 1815, the British returned islands to the Danish, in whose possession they remained for a century.

In 1735, to facilitate colonization and hasten a return on their investment, the Danish West Indies and Guinea Company surveyed the island using Centerline Road (also, Queen Mary Highway, or route 70) as the baseline (Hopkins 1987, Lewisohn 1964). Soon after, a network of properties, most ranging in size from 60 to 120 ha, was available for planters from various European countries to initiate agricultural activities. By 1737, 43 cotton estates had been surveyed, and by 1740, the number had grown to 113 (Tyson 1996). Cotton plantations sold for 70 percent less than sugar cane lands, required fewer slaves and buildings to operate, and yielded a crop within 6 months. Most cotton plantations were on dry sites with steep, rocky soils. In 1750, nearly 60 percent were concentrated in the area from Christiansted southwest to Canegarden Bay, then east to East End Bay. Most others were in the island's southwestern corner, extending from slightly east of Long Point northwest to Frederiksted,

then south to Sandy Point. By 1767, the distribution had changed, with most plantations at the eastern end of the island. Crucian cotton plantations were prosperous from about 1740 to 1770, with the decade between 1745 and 1755 considered as the boom years. Between 1767 and 1792, more than 50 plantations ceased to produce. By 1815, the cotton industry was largely nonexistent. Attempts to reestablish it in the 1860s and again in the early 1900s were unsuccessful. In 1916, planters abandoned the cultivation of cotton on St. Croix.

Planters on St. Croix set up sugar cane and cotton plantations simultaneously, with the former on the more humid sites. By 1742, St. Croix had 120 sugar cane plantations (Dookhan 1974). As early as 1770, sugar cane cultivation had expanded over much of the island, in some instances replacing earlier plantings of cotton. Although cane production was demanding, it flourished during the late 1700s and early 1800s "when sugar was king" (Lawaetz 1991, page 222). In 1796, more than one-half of the island was planted in sugar cane (Lawaetz 1991, O'Neill 1972), and 114 windmills and 144 animal-driven mills ground the cane (Lewisohn 1964). Most ruins visible today, including houses and mills, were constructed between 1750 and 1820 when the island was a major sugar producer (Copeland 1976). Typically, planters used about 75 percent of their lands for growing and processing sugar and the remainder for homes, pasture, and woodlands. Planters frequently faced hardship from hurricanes and droughts, both capable of wreaking untold damage. High insurance rates, debts, and mortgages were often part of staying in business. Diseases such as malaria, cholera, and yellow fever killed slaves and landowners alike. Labor problems—rebellions and crop burning—were a constant concern (Tyson and Highfield 1994). "Once in the sugar and rum business, a planter was in it for better or worse" (Lewisohn 1964, page 23).

The Spanish first brought slaves into the Caribbean in 1505, and in the early 1600s the British, Dutch, and French also imported them (Lawaetz 1991). In 1674, the Danish West India and Guinea Company was granted the first monopoly in the Danish slave trade, which was still in effect when St. Croix was purchased nearly 60 years later (Green-Pedersen 1996). In 1792, the King of Denmark abolished the slave trade in the Danish West Indies, but the law remained inoperative until 1803 (Lawaetz 1991). In 1833, the British Parliament's emancipation of the slaves in the British colonies had an impact in the nearby Danish West Indies (Holsoe 1996). To maintain slavery, planters had to improve social and working conditions.

The treatment of slaves on St. Croix and other Danish islands was apparently not as bad as elsewhere in the Caribbean (Lewisohn 1964), particularly after 1833 with the adoption of strict laws regarding their working hours and provision. Slaves on St. Croix grew their own crops on small plots of land (Tyson and Highfield 1994) and could sell their surplus, save money, and ultimately buy their freedom at court-appraised prices. Consequently, the Danish islands had a relatively high number of free laborers. Sometimes, however, the appraisals were set too high to pay (Holsoe 1996). In 1848, rumors circulated regarding emancipation, and some slaves planned an uprising. On July 3, 1848, during the insurrection, Governor General Peter von Scholten abolished slavery in the Danish West Indies. At that time, the population of slaves was about 26,000 on St. Croix and 44,000 throughout the Virgin Islands.

After emancipation, estate expenses surged on St. Croix, but sugar production continued through improvements in cultivation and manufacturing (Jensen 1998). From 1850 to 1900, the area in sugar cane production declined from 8175 to 6600 ha and by 1915, to 5050 ha. Sugar production, however, gradually concentrated on the most fertile and arable lands. The number of steam mills, which first appeared on Estate Hogensborg in 1816 (Lewisohn 1964), surpassed the combined number of windmills and animal-powered mills by 1865 (Jensen 1998). The greatest agricultural advance was the Central Factory on Estate Richmond near Christiansted, which began operations in 1878. In October of that year, however, the island's low wages and poor labor conditions led to a revolt of the agricultural workers in Frederiksted (Dookhan 1974). Laborers ransacked the town, burned several private and public buildings, and heavily damaged some of the surrounding plantations. Danish loans to repair the losses temporarily revitalized the estate system and stimulated sugar output from 1880 until the turn of the century. The economy of the Virgin Islands, however, continued to decline mainly from competition, first experienced during the 1820s, from lower-priced beet and cane sugars produced elsewhere (Dookhan 1974, Jensen 1998).

In 1895, the crisis in the sugar industry led to the establishment of a Botanical Experiment Station on Estate La Grange to encourage diversification of the economy (Dookhan 1974, Willocks 1995). The results were disappointing because of insufficient funds for machinery and technical assistance and problems associated with the site. In 1910, an agricultural experiment station was started at Anna's Hope to develop types of sugar cane resistant to pests and diseases. By 1916, however, only three factories—La Grange, Bethlehem, and St. Croix—accounted for 88 percent of the sugar production on the island. The economic decline in Danish West Indian agriculture from 1848 to 1917 was inevitable as long as sugar cane remained the island's main crop.

During the Civil War, the United States recognized the need for a naval station in the West Indies; however, the U.S. Senate did not ratify the treaty drawn up in 1867 to purchase St. Thomas and St. John (Dookhan 1974, Hatch 1972, Tanshill 1932). Again, during the Spanish-American War, the United States attempted to purchase the islands, but this time the Danish did not approve the treaty. Finally, in March 1917, the United States purchased the Virgin Islands from Denmark "as a coaling depot and a military base to promote or safeguard vital United States economic interests in the region" (Dookhan 1974, page 262), among them the Panama Canal. For the Danes, it marked the end to nearly 250 years of colonialism; for the United States, it was a new venture 1 week before its entrance into World War I (O'Neill 1972).

## U.S. Involvement: 1917-2000

The U.S. Navy first administered the Virgin Islands, a "period which was satisfactory to no one" (Lewisohn 1964, page 9), followed by the Department of the Interior from 1931 to 1936 (O'Neill 1972, Willocks 1995). The inhabitants of the islands received U.S. citizenship in 1927, but the United States initially retained the Danish system that gave full power to an appointed governor (Rogozinski 1999). Under the Basic Organic Act of 1936, the U.S. constitution replaced the old Danish laws and practices. Through the mid-1950s, the United States appointed governors from the mainland; later, they were selected from the islands. The Elective Governor Act was passed in 1968, and the first elected governor took office in 1970. Island residents cannot vote for the President but do elect a delegate without voting rights to the U.S. House of Representatives.

Soon after taking possession of the rum-producing Virgin Islands, the U.S. Government passed the 18th amendment to the Constitution, prohibiting the importation and sale of alcoholic beverages. "Forbidding the use or sale of this fragrant staple to grown men was almost beyond the ability of sensible grown Cruzans [Crucians] to imagine. This had been the first action taken by the new master which made the islanders, nourished on cane juice, sugar, molasses and rum, wonder at his sanity. Everyone knew the sugar process gave off molasses, molasses gave off rum, a powerful agent which loosened the joints and stiffened the backbone of the economy" (Lewisohn 1970, page 372). Lower sugar prices and decline in rum production caused many younger islanders to depart from St. Croix, creating a labor shortage (Lawaetz 1991). In the late 1920s, Puerto Ricans, many from the islands of Vieques and Culebra, migrated to St. Croix, helping the island's economy during a difficult period.

In 1929, the Bureau of Efficiency reported on the social and economic conditions of the Islands. During the visit, the Danish company that controlled sugar production closed, leaving many islanders without income. In 1931, President Hoover referred to the Virgin Islands as the "effective poorhouse" of the United States (Lewis 1972, page 70). On St. Croix, for example, 14 owners held 70 percent of the land (O'Neill 1972). In 1932, Roosevelt's New Deal created the Virgin Islands Company (VICO), and in 1933, the 21st amendment conveniently repealed prohibition. Similar to the Federal Public Works Administration, VICO placed the U.S. Government in the business of growing and refining sugar, distilling rum, and developing water supplies and power (O'Neill 1972). The continuing Depression and World War II occupied the United States for the next 15 years.

In 1950, the Virgin Islands had no local university or industry, and tourism was virtually nonexistent. In 1952 the new Tourist Development Board started to promote tourism (Dookhan 1974), and in 1956 National Geographic highlighted the islands as a

readily accessible "tropical playland" (Scofield 1956, page 201). In 1959, Cuba's revolution closed Cuba to American visitors and stimulated tourism in the Virgin Islands. The decade of the 1960s witnessed the establishment of the University of the Virgin Islands (UVI) (Dookhan 1974) and a rapid expansion of the economy, including the lucrative tourist industry—enhanced by the islands' location, climate, scenic beauty, and imaginative leadership (Lewis 1972).

The Virgin Islands are now promoted as a paradise, and 1-day tourists debark from cruise ships, mainly in St. Thomas, for a duty-free splurge on jewelry, perfumes, tobacco, and liquor. The free port status dates back to a 1764 ordinance that opened trade for St. Thomas and St. John (and later St. Croix) to other colonies in the Americas (Dookhan 1974). Moreover, the Danish specified continuing the Islands' free port status as one of the conditions of sale (Copeland 1976).

Tax incentives also attracted industry. In 1962, the Virgin Islands legislature authorized Harvey Aluminum Corporation to build a plant to refine bauxite ore into aluminum on St. Croix and in 1965 approved the Hess Oil Refinery (O'Neill 1972, Rogozinski 1999, Willocks 1995; fig. 1). Both provided employment but introduced environmental problems. Harvey closed its plant in 1985, and in 1995 Alcoa occupied the site but later closed. Smaller factories in the Virgin Islands today make clocks, textiles, rum, and pharmaceutical products. Moreover, a small group of artisans, many on St. Croix, make furniture and wooden novelty items (Francis 1995, Somberg 1976). Throughout the islands, the local government remains the major employer (Lewis 1972).

## Population Trends: Residents and Tourists

In 1643, a French writer reported that 600 people lived in St. Croix, and toward the end of the century, perhaps 800 lived on the island (Lawaetz 1991, Lewisohn 1970). By the mid-1740s the population had increased only to 2,080, but by 1755 it had rapidly climbed to over 10,200 (fig. 4). For the 100-year period between 1770 and 1870, the population was about 22,000 or greater, with the peak years around 1800 when it averaged between 25,000 and 30,000. In 1803, about 88 percent of the estimated 30,000 island residents were slaves.

From 1850 to 1917, the postemancipation era, both ex-slaves and ex-slave owners had to adjust to a new labor situation (Dookhan 1974). During this period, the population of St. Croix declined from 23,730 to 14,900. The rural population diminished by more than one-half, while the urban population remained relatively stable (Jensen 1998). World War I had reduced shipping from the Virgin Islands' major port at St. Thomas "nearly to the vanishing point" (Dookhan 1974, page 237). In response, local people migrated to find better living conditions. In 1927, Crucian cane growers were forced to recruit Puerto Rican laborers from the islands of Vieques and Culebra, where economic conditions had deteriorated.

Population decline continued on St. Croix through 1930, when the census tallied only 11,413 individuals, the fewest in nearly two centuries (Lawaetz 1991). By the mid-1930s, the poor living conditions throughout the Virgin Islands had forced some 10,000 islanders to depart, many for Harlem in New York (O'Neill 1972). From 1940 to 1960, the population of St. Croix was relatively stable, increasing slightly from 13,000 to 15,000. Between 1960 and 1980, however, the population more than tripled to about 50,000 (fig. 4). Some of the new arrivals were migrant laborers from other Caribbean Islands who settled in St. Croix. Many, however, were "continentals" from the United States investing in properties, industries, homes, and businesses (Lawaetz 1991). This sudden reversed migration, accompanied by erratic development, threatened the natural, historical, and cultural resources of the island. Since 1980, however, the population on St. Croix has remained relatively stable, rising only to a little more than 53,000 by the new millennium.

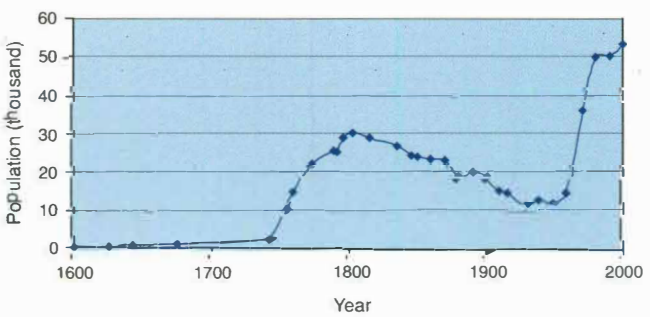



Figure 4—Population trends of settlers on St. Croix. (Sources: Anonymous. 1950, Jensen 1998, Lawaetz 1991, Lewisohn 1970, Rogozinski 1999, U.S. Department of Commerce 2003, Westergaard 1917.)

In 1952, the Virgin Islands Tourist Development Board began to promote the Virgin Islands as a refuge from cold northern winters (Willocks 1995); also, in 1962, the Alexander Hamilton Airport (today the Henry E. Rohlsen Airport) opened on St. Croix. Tourism increased dramatically on all the islands, a trend that has continued for St. Thomas and St. John into the 21st century. St. Croix, however, has suffered a recent decline in tourism. During 1990, about 181,400 tourists and excursionists spent time on St. Croix. By 1999, that number had declined to 146,400, and by 2003, to only 114,100, a 13-year decrease of 37 percent (U.S. Virgin Islands Bureau of Economic Research 2004). Some loss in tourist visits was caused by the discontinuation of cruise ship stops at Frederiksted. Numerous hurricanes from 1989 to 1998, along with associated impacts on the economy, appear to have negatively impacted population growth and tourism, at least temporarily.

## History: Sion Farm and Estate Thomas

From 1735 through 1754, the Danish West India Company surveyed and distributed properties on St. Croix. Estate Thomas was the name given to "matricul" (local term for register) 24 in Queen Quarter when measured by Danish surveyors in the late 1740s. William Thomas first claimed the property on May 16, 1749 (Rigsarkivet 1742-1915: 1749-50, 1759; Ryberg 1945; table 5). Planters had acquired and occupied the properties surrounding Estate Thomas several years earlier, indicating that Estate Thomas, with its steep, rugged terrain, had marginal agricultural value. The Blondel map of 1667 (Hutchins and others 1990), the only reliable source of information regarding settlement during the French era, does not indicate that the property was inhabited prior to Danish occupation of the island (Tyson 2005, see endnotes).

The Cronenberg-Jaegersberg map (Hutchins and others 1990), prepared in late 1749 and early 1750, locates the Thomas settlement, a single house

**Table 5—Ownership, land use, and population on Sion Farm, 1750-1963**[a]

| Year | Owners | Sugar area | Population (free + slave) |
|---|---|---|---|
| | | *(ha)* | |
| 1750 | Nicholas Tuite | —[b] | — |
| 1755 | Nicholas Tuite | — | 10 + 136 |
| 1760 | Nicholas Tuite | — | 4 + 187 |
| 1766 | Nicholas Tuite | — | 9 + 309 |
| 1772 | Nicholas Tuite | — | 5 + 333 |
| 1780 | Robert Tuite | — | 5 + 302 |
| 1787 | Robert Tuite | 154 | 281 |
| 1792 | Robert Tuite | 146 | 5 + 274 |
| 1796 | Robert Tuite | 146 | 258 |
| 1805 | Robert Tuite | 128 | 2 + 292 |
| 1815 | Charles McCarthy[c] | 98 | 4 + 292 |
| 1830 | Charles McCarthy[c] | 132 | 5 + 239 |
| 1835 | Royal Loan Commission[d] | — | — |
| 1841 | Royal Loan Commission[d] | 117 | 20 + 212 |
| 1847 | Royal Loan Commission[d] | 117 | 17 + 232 |
| 1855 | Royal Loan Commission[d] | 113 | 120 |
| 1861 | John Christmas[c] | 109 | 128 |
| 1876 | State Treasury[e] | 110 | — |
| 1880 | State Treasury[e] | 110 | 104 |
| 1905 | St. Croix Sugar Factory[c] | — | — |
| 1911 | St. Croix Sugar Factory[c] | 130 | 120 |
| 1917 | St. Croix Sugar Factory[c] | 106 | 76 |
| 1924 | St. Croix Sugar Factory[c] | 74 | — |
| 1928 | West India Sugar Factory[c] | — | — |
| 1931 | Charles Andrew de Chabert[c] | — | — |
| 1934 | U.S. Government[c] | — | — |
| 1953 | Virgin Islands Corporation[f] | 0 | 0 |
| 1963 | USDA Forest Service[g] | 0 | 0 |

[a] Sources: Rigsarkivet (Danish National Archives, Copenhagen): 1742-1915: 1787, 1792, 1796, 1805; St. Croix Recorder of Deeds, 1928-present.
[b] — = Not available.
[c] Acquired.
[d] By foreclosure.
[e] Acquired at auction.
[f] Sugar cultivation discontinued on Estate Thomas portion of Sion Farm; forestry research begins.
[g] Virgin Islands Corporation transfers Estate Thomas from Sion Farm to U.S. Government (USDA Forest Service).

surrounded by sugar cane fields, just north of the southeast corner of Estate Thomas (Tyson 2005, see endnotes). Thomas or his overseer would have occupied this house at that time (Rigsarkivet 1742-1915). A small village, with houses made of wattle and daub, and 14 slaves, would most likely have been nearby. This settlement was probably abandoned in the 1750s when Estate Thomas was consolidated with Sion Farm. No documentary evidence exists for settlement sites on Estate Thomas after 1750.

A 900 $m^2$ cattle pen dating from the late $18^{th}$ century was also documented within the boundaries of Estate Thomas. The pen may have been near the old Thomas settlement; however, since that land was suitable for sugar cultivation, and because cattle pens were easy to construct, perhaps it was built at another location. Archeological remains associated with animal husbandry, cultivation of provisions, and charcoal production by African-Crucians may also exist within Estate Thomas.

Estate Thomas was likely a source of charcoal and provisions for Sion Farm slaves. Inventories of Sion Farm prepared between 1776 and 1806 indicate as many as 30 ha planted in crops labeled as Negro provisions (Rigsarkivet 1787, 1806; Tyson 2005, see endnotes). The crops would have included cassava, corn, melons, pumpkins, tanyas, tobacco, yams, and other root crops (Tyson and Highfield 1994). Typically, slaves commuted to provision grounds from their village, but the most active erected temporary thatch shelters in the field. These practices would have been more common after emancipation in 1848.

Sion Farm (including Estate Thomas) has had an eventful past characterized by a two-century record of sugar production under a dozen different owners, both private and public (table 5). Little information, however, is available about Estate Thomas per se while it was incorporated with Sion Farm. Danish land tax records aggregate data on land use and population and list them for Queen Quarters 26 to 27, which was the main settlement area for Sion Farm. An 1849 inventory of Sion Farm showed that one-half of Estate Thomas was planted in sugar cane and the remainder was in pasture.

In 1750, Nicholas Tuite, a wealthy planter who had recently migrated from Montserrat, bought Estate Thomas. Tuite combined the property with several other plantation plots (Queen Quarters 26, 27, and 33b) to form a 213-ha complex that later was known as Sion Farm. For the next 200 years, the inhabitants of Sion Farm lived in a single settlement on either side of the boundary between Queen Quarters 26 and 27, about 1.5 km southwest of Estate Thomas.

Charles McCarthy acquired Sion Farm in 1815 and held it until 1835 when the Royal Loan Commission (Danish Government) assumed control because of unpaid taxes and debts (Hatchette 1858; table 5). The Government retained title and leased Sion Farm until 1905, when the St. Croix Sugar Factory bought it. The Sugar Factory, which operated the Central Factory on Richmond Estate near Christiansted, later went bankrupt. In 1928, the West Indian Sugar Company acquired Sion Farm, and in 1931, sold it to Charles Andrew de Chabert, a local merchant and landowner. In 1934, the U.S. Government acquired all but 25 ha of Sion Farm and placed it under the administration of the newly created VICO, a Federal enterprise that reactivated the Bethlehem central factory and resumed sugar cultivation on many estates, including Sion Farm. In 1949, VICO phased out and transferred all assets and property to VICORP (Willocks 1995). In 1953, VICORP set aside Estate Thomas for research in forestry, and the IITF began several field studies (Nobles 1960). In 1963, the Forest Service bought Estate Thomas when VICORP closed its sugar operations (O'Neill 1972).

Virtually all of Sion Farm was cleared of native vegetation at one time to grow sugar cane. Moreover, the owners of Sion Hill, bordering Estate Thomas to the west, probably cultivated sugar cane on portions of Estate Thomas where the hills remained in cultivation until 1928 and the valleys until 1953 (Somberg 1976, Ward and others 2002). Land use maps prepared in 1947-48 for St. Croix show that 6 ha of Estate Thomas were planted in vegetables and a portion in sugar cane (Tyson 2005, see endnotes). From the mid-1950s through the mid-1960s, importing temporary workers from other Caribbean Islands resolved the shortage of labor to work the sugar harvest (Lawaetz 1991). Sion Farm was one of the four estates where VICORP housed the migrant labor force. In 1964, about the time when Federal subsidies for sugar production ended, VICORP sold its land to a subsidiary of Harvey Aluminum. Today, the Sion Farm Great House, apparently built around 1860, is the Lieutenant Governor's mansion (fig. 5).

Figure 5—Sion Farm Great House, painting, circa 1860. (St. Croix Landmarks Society Library and Archives, Photograph Collection.)

## *Forest Service Activities: 1930-62*

The bankruptcy of the West Indian Sugar Company in 1930 caused chaos and unemployment in the agricultural sector of St. Croix (Anonymous 1950, Cederstrom 1950), and the Bureau of Efficiency of the U.S. Navy requested that the Forest Service survey forest conditions in the Virgin Islands (Nobles 1960). At that time, a resident forester reported on the island's climate, population growth, land use, land ownership, forests, and forest-based industries (Cramer 1930, see endnotes). During the next two years, windbreaks and pasture shade trees were planted as part of the forestry effort on St. Croix. The forestry program was discontinued, however, because of inadequate transportation, high costs, and a disinterested public (Nobles 1960). Looking to the future, the report suggested the possible establishment of national forests on St. John and St. Croix under the direction of the Forest Supervisor in the Luquillo National Forest. To some extent, the U.S. Government achieved this goal, although not as envisioned. The Virgin Islands National Park was created on St. John in 1956, and the Forest Service purchased Estate Thomas on St. Croix in 1963.

The U.S. Government chartered VICO in 1934, authorizing it to operate agricultural lands and industries as part of the economic rehabilitation program (Cederstrom 1950). From 1932 until 1950, VICO gathered research data on new varieties of plants and breeds of animals, and general farm practices (Anonymous 1950). The company, with a dominant position in the agricultural program of the Islands, provided wage employment in factories and in the field and helped self-employed small farmers by processing their sugar cane (Anonymous 1947). In 1940, farms occupied nearly three-quarters of the island, of which cropland covered 22 percent, pasture 44 percent, and other uses, including woodland, 8 percent.

Between 1940 and 1952, Forest Service staff members occasionally visited the Virgin Islands in cooperation with other government agencies (Nobles 1960). As early as 1940, thinning was envisioned as one way to increase raw material for the furniture and wood-turning industry on St. Croix, especially for stands containing small-leaf mahogany (Bevan 1940). In 1950, a research program was suggested to improve farming and related enterprises, soil and water conservation, and notably, forest management and reforestation practices (Anonymous 1950).

Foreseen as benefits of the proposed forestry efforts were timber for fuel and charcoal, posts, and possibly export; improved infiltration of rain water; and the provision of outdoor recreation areas for tourists. Suggested activities for the forestry program included:

- Research in forest establishment, regeneration, stand improvement, and utilization
- Technical assistance in forestry for small landowners linked to agricultural extension
- Use of technical information from nearby Puerto Rico
- Planting of trees on cleared lands

Beginning in 1950, the Soil Conservation Service financed travel for Forest Service personnel to help promote forestry. In 1952, the Forest Service helped set up a small nursery at the St. Croix Experiment Station, and between 1952 and 1954 attempted aerial seeding that failed (Rotty 1955, see endnotes; table 6). In 1953, VICORP reserved Estate Thomas as a research and demonstration area, providing funds for a forester and S&PF activities. Forestry activities included research, extension, tree planting, forest management, tree harvesting, and milling of forest products (Anonymous 1956). By 1955, VICORP had installed a saw rig and treatment plant on Sion Farm. One intended market was native woodworking shops producing mahogany novelties. In 1956, foresters planted Burmese teak on Estate Thomas lands that had been growing sugar cane since 1920 (Nobles and Briscoe 1966c).

Forestry goals for the next decade included growing more small-leaf and big-leaf mahogany in existing stands on Estate Thomas and elsewhere on St. Croix (Anonymous 1955, Nobles 1960; table 6). The IITF mahogany research program was summarized as follows (Francis 2003b, pages 332-333):

> The Institute [IITF] has conducted low-key but steady research on mahogany from its first activities to the present. The research has sometimes been pioneer and original and sometimes corroborative. Considerable effort has been made through informal trials, reported briefly in such sources as annual reports. Most of the early

*Estate Thomas forestry crew in 1972. Standing left to right: Ponce, Bough, Frederiksen, Colón, and Baltimore; kneeling left to right: Rosa, Williams, and Villafañe.*

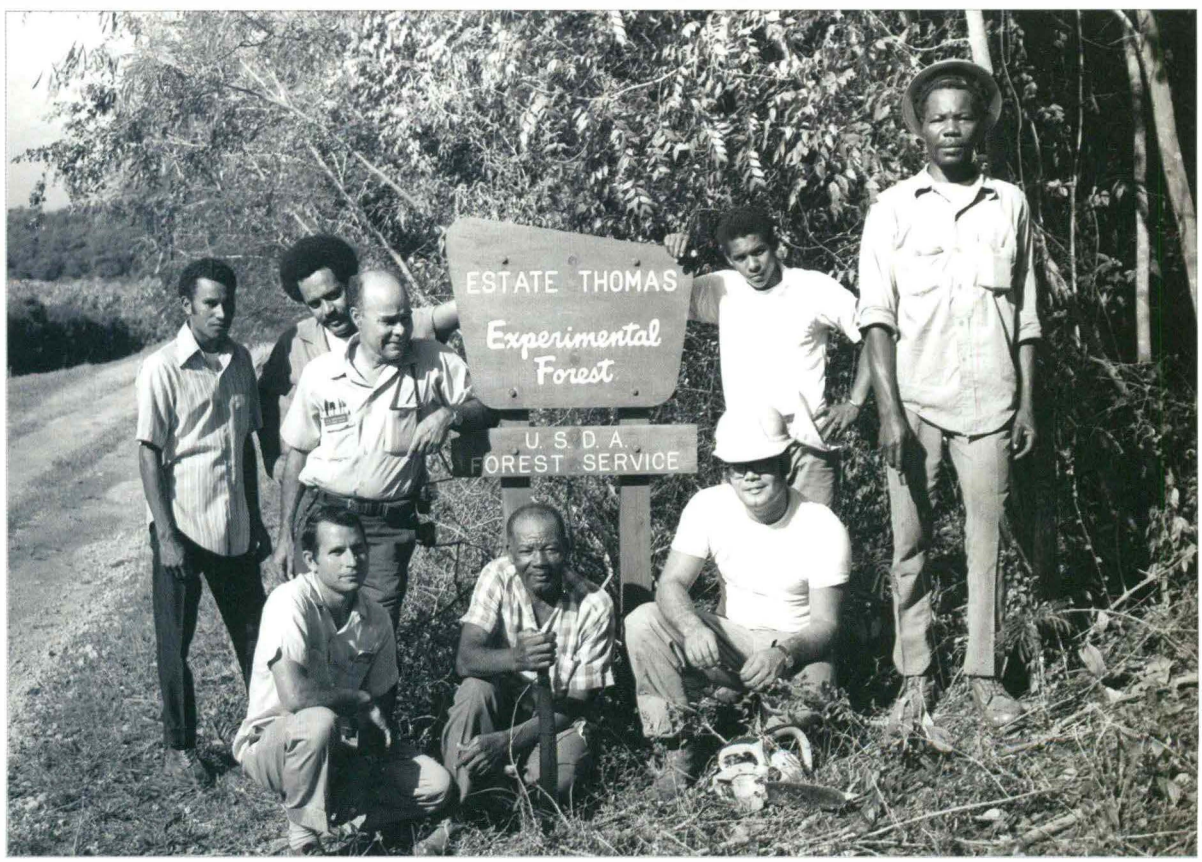



Photo courtesy of IITF.

**Table 6—General results of forestry activities (research and management) on St. Croix, 1952-62**

| Topic | Source | Comments (observations or conclusions) |
|---|---|---|
| Nursery | Rotty 1955, see endnotes | Nursery established at St. Croix Experiment Station in 1952 produces seedlings for future plantings. |
| Aerial seeding | Rotty 1955, see endnotes | Attempts to aerial seed small-leaf mahogany during 1952 to 1954 failed. |
| Direct sowing of seed | Anonymous 1955 | Broadcasting big-leaf mahogany seed on humid sites at Davis Bay seems promising. |
| Growth rates | | Small-leaf mahogany at Bellvue Estate appears to grow more rapidly at lower basal areas. |
| Seed germination | Anonymous 1956 | Germination for both mahoganies erratic and generally low. |
| Seed collection | | Techniques for mahogany seed collection and handling improved. |
| Direct sowing of seed | | Broadcasting seed of both mahogany species gives generally poor results. |
| Underplanting in rows | | Sturdy mahogany seedlings of both species survive bare-root planting on good sites in favorable years. |
| Seed treatments | | Teak germination is enhanced by pretreatment of seeds. |
| Regeneration | Anonymous 1957 | Well-developed potted seedlings of both mahogany species survive well in favorable years; for both species, most reliable method is to plant vigorous stock with a ball of earth. |
| Teak weeding | Anonymous 1958 | Planted teak capable of high survival but weeding costly; weed control with herbicides inconclusive. |
| Teak survival | Anonymous 1959 | Teak losses are due to stock size, planting techniques, and unseasonable droughts. |
| Seed handling | | Big-leaf mahogany seeds are collected in February-March, sown immediately in plastic pots using alluvial soil, two seeds per pot; propagated under light shade, and planted in September. |
| Mahogany planting | Nobles 1960 | Small-leaf mahogany is planted in strips 6.0 to 7.5 m apart, with seedlings planted 3 m apart within strips. |
| Forest improvement | | Natural forest stands with small-leaf mahogany at Estate Thomas are thinned to improve growth. |
| Timber utilization | | Old trees at various sites on island are cut and milled as service to local community. |
| Seed germination | Anonymous 1960 | Two seeds are sown in plastic pots for both mahoganies; outplanting as in previous years. |
| Stand improvement | | Liberation thinnings of past year are continued at Estate Thomas. |
| Teak performance | | Future of teak is doubtful at Estate Thomas because of poor form and growth. |
| Wood preservation | Anonymous 1961 | Treatment of fence posts with pentachlorophenol in diesel oil helps meet cattle industry demand. |
| Sawtimber utilization | | Artisans use cut timber for specialty purposes. |
| Hybrid mahogany | Anonymous 1962 | Seed is collected for distribution to foreign countries. |
| Research studies | | Adaptability trials begin with Spanish cedar (*Cedrela mexicana* L.), primavera (*Cybistax dionnell-smithii* (Rose) Seibert, and Caribbean pine (*Pinus caribaea v. hondurensis*). |
| Furniture, novelties | Anonymous 1963 | Sawmill run intermittently to process lumber for specialty purposes. |

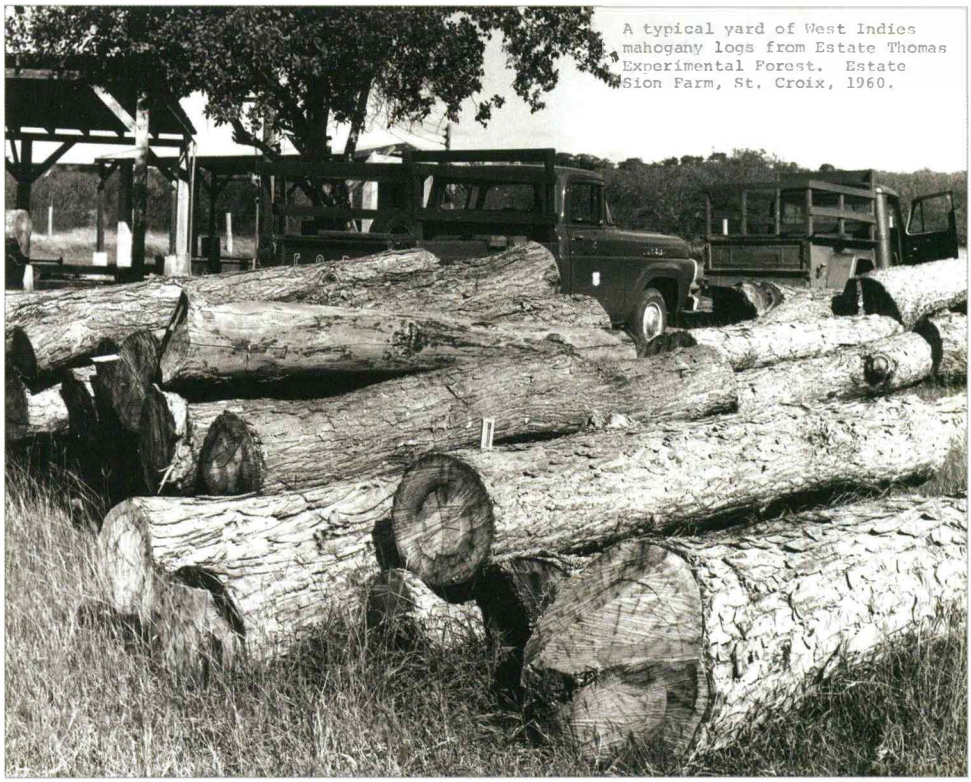



Photo courtesy of IITF.

*Small-leaf mahogany* (Swietenia mahagoni) *logs harvested from Estate Thomas in 1960 for use by local artisans.*

*American No. 1 circular sawmill operated by the U.S. Department of Agriculture Forest Service on Sion Farm during the late 1950s and the early 1960s.*


Photo courtesy of IITF.

mahogany effort was utilitarian, on how to grow nursery seedlings and establish plantations.

This summary accurately describes the efforts made on St. Croix.

After introduction to St. Croix, small-leaf mahogany spread to abandoned farmlands and pastures on many estates, notably Bellevue, Little Princess, and Thomas about 3 km west of Christiansted, where about 100 ha were growing in the mid-1950s (Anonymous 1955, Francis 2002, Wadsworth 1947, Ward and others 2002). Foresters, dating back to their earliest visits, were interested in thinning these stands to improve their growth and development (Bevan 1940, Nobles 1960; table 6). In 1961, they thinned about 9 ha of small-leaf mahogany within Estate Thomas to improve growth (Anonymous 1962). In 1962, they released 109 crop trees from competition and subsequently measured them along with untreated controls periodically until 1996 (Francis 2003a). During the 34-year period of measurement, the crop trees grew in d.b.h. at a rate of 0.25 cm/year, 50 percent faster than the unthinned control trees.

Among the many field investigations on St. Croix during the period from 1953 to 1972 were the following (tables 6, 7, and 8):

- Experimentation in seed collection, storage, handling, treatment, and germination
- Attempts at aerial and broadcast seeding on different sites
- Experimentation with bare-root and potted-stock seedlings under different conditions
- Observations of early seedling establishment, tending, and growth
- Weed control by mechanical and chemical means
- Stand improvement—release of naturally occurring small-leaf mahogany by thinning
- Sawmilling (on Sion Farm and later at Estate Thomas) for local use
- Fence-post treatment (on Sion Farm and later at Estate Thomas) for local use
- The initiation of formal research (adaptability) trials

Inconsistent experimental results forced the repetition of several experiments. Rainfall, variable in quantity and distribution from one year to the next,

**Table 7—Additional forestry activities, mainly plantings, on St. Croix from 1954 to 1972**

| Study (species) name | Date (start) | Location[a] | Size | Activity |
|---|---|---|---|---|
| | | | *(ha)* | |
| Teak[b] | Dec. 1954 | ET–D, E | 10.1 | Planted 17,900 potted plants and stumps between Dec. 1954 and Jun. 1958; seedlings weeded and saplings thinned several times; posts harvested recurrently after Aug. 1963; 11 kg of seed collected in Mar. 1965; timber stand improvement in Apr. 1973; residual stand destroyed by Hurricane Hugo in Sept. 1989 |
| Mahogany[c] | Sept. 1955 | ET–G | 2.1 | Planted 2,640 small-leaf mahogany and 57 big-leaf mahogany; survival in Apr. 1969, 9 percent; thinned in May 1970 |
| Teak | Aug. 1956 | Sion Hill | 0.8 | Planted 3,800 stumps between Aug. 1956 and Sept. 1959; survival in Feb. 1973, 1 percent |
| Big-leaf mahogany | Sept. 1956 | Sion Hill | 6.5 | Planted 2,400 seedlings between Sept. 1956 and July 1958; survival in Aug. 1958, 90 percent and in Jun. 1959, 35 percent |
| Small-leaf mahogany | Sept. 1958 | Sion Hill | 6.5 | Planted and replanted 3,300 seedlings between Aug. 1958 and July 1968; survival in Apr. 1969, 50 percent |
| Plum pudding mahogany | 1961 | St. Croix | — | Located, tagged, and measured plum pudding mahogany trees at various sites on island; 702 measurements compiled in Apr. 1970; study closed in Feb. 1973 |

*continued*

**Table 7—Additional forestry activities, mainly plantings, on St. Croix from 1954 to 1972 (continued)**

| Study (species) name | Date (start) | Location[a] | Size | Activity |
|---|---|---|---|---|
| | | | *(ha)* | |
| Mahogany root pruning | Aug. 1963 | ET–G | 0.2 | Planted 100 root-pruned seedlings; released survivors in Aug. 1964; survival in Jan. 1973, 58 percent |
| Hybrid mahogany | May 1965 | Sion Hill | 6.5 | Planted 200 seedlings between May 1965 and Jan. 1966; tallest tree in Feb. 1973, 9 m |
| Mahogany plantation | July 1965 | Sion Hill | | Planted 485 small-leaf and hybrid mahogany seedlings; survival in Feb. 1973, 32 percent; tallest tree in Feb. 1973, 3.7 m |
| Chittagong[d] | Aug. 1967 | ET–G | — | Planted 63 seedlings; survival in Feb. 1973, 87 percent; tallest tree in Feb. 1973, 6.7 m |
| Spanish cedar[e] | Aug. 1967 | ET–G | — | Planted and replanted 2,070 seedlings; thinned planting 7 times in 5 years; tallest tree in Feb. 1973, 7.6 m |
| Hybrid mahogany | July 1968 | Sion Hill | 2 | Planted and replanted 1,580 seedlings; survival Feb.1973, 81 percent |
| Spanish cedar | July 1968 | Sion Hill | — | Planted and replanted 550 seedlings; survival in Feb.1973, 67 percent |
| NPS hybrid mahogany | Feb. 1969 | Sion Ridge | — | Planted 6,700 seedlings between Feb.1969 and July 1969; released survivors 5 times; survival in May 1970, 50 percent; planted 1,300 additional seedlings between July 1972 and Sept. 1972; largest hybrid in Feb. 1973, 5.5 m tall |
| NPS small-leaf mahogany | Feb. 1969 | Sion Ridge | — | Planted 800 seedlings between Feb. 1969 and July 1969; released survivors 5 times; survival May 1970, 30 percent |
| Lignum-vitae[f] | Oct. 1969 | ET–G | — | Planted 144 seedlings; released survivors several times; survival in Feb. 1972, 94 percent; tallest tree in May 1974, 1.7 m |
| NPS—Christmas tree trials | Aug. 1971 | Sion Ridge | — | Planted 75 *Cryptomeria japonica*, 50 *Casuarina equisetifolia*, and 75 *Araucaria heterophylla* |
| Spanish cedar | Sept. 1971 | ET–G | — | Planted 152 seedlings; survival in Feb. 1972, 90 percent; released survivors in Jan. 1973 |
| Toona[g] | Sept. 1971 | ET–G | — | Planted 150 seedlings; weeded in 1972 and released survivors in 1973; fire eliminated most in Apr. 1974 |
| Hybrid mahogany | Sept. 1971 | Sion Farm | — | Two areas, one thinned in 1981 and the other at unknown date; both measured in 1986 |
| Hybrid mahogany | July 1972 | Salt River | — | Planted 1,230 seedlings, partially released survivors in Aug. 1972 |
| Small-leaf mahogany | 1986 | ET–C | — | Previously thinned natural regeneration of unknown age; mean basal area of 27 $m^2$/ha; largest trees on north-facing slopes |

— = Unknown.

[a] ET = Estate Thomas; A, B, D, E, and G are blocks or management units within the estate; NPS = National Park Service.

[b] *Tectona grandis* L. f.

[c] Big-leaf mahogany, *Swietenia macrophylla* King; small-leaf mahogany, *S. mahagoni* Jacq.; Plum pudding mahogany, *S. mahagoni* with attractive grain; hybrid is a cross between *S. macrophylla* and *S. mahagoni*.

[d] *Chukrasia tabularis* A. Juss.

[e] *Cedrela odorata* L.

[f] *Guaiacum officinale* L.

[g] *Toona ciliata* Roem.

**Table 8—Sites used by U.S. Department of Agriculture Forest Service on St. Croix for formal studies, field experiments, and operations**

| Estates | Topics |
|---|---|
| | **Formal studies** |
| Annaly Bay | Species adaptability |
| Bethlehem Upper New Works | *Cedrela* plantings, hybrid mahogany growth |
| Betzy's Jewel | Species adaptability and hybrid mahogany growth |
| Bodkins | Species adaptability, hybrid mahogany growth, and *Cedrela* plantings |
| Bog of Allan | *Cedrela* plantings |
| Bugbyhole | Hybrid mahogany growth |
| Cane Bay | Hybrid mahogany growth |
| Hams Bluff | Species adaptability, hybrid mahogany growth, and *Cedrela* plantings |
| Jealousy | Mahogany provenance trials |
| Jolly Hill | Mahogany root pruning |
| Judith Fancy | Species adaptability |
| Kings Hill | Species adaptability |
| Sion Hill | Hybrid mahogany growth |
| Solitude | Species adaptability |
| Estate Thomas | Species adaptability, hybrid mahogany growth, *Cedrela* plantings, teak mowing, mahogany root pruning, mahogany frilling, and mahogany provenance trials |
| | **Field experiments and operations** |
| Annaly | Direct seeding of big-leaf mahogany |
| Bellvue | Thinning of small-leaf mahogany |
| Bodkins | Planting of hybrid mahogany in 1961 |
| Cane Bay | Planting of teak stumps in 1958 |
| Cotton Valley | Mahogany seedlings stored on site |
| Davis Bay | Hybrid mahogany first seen and seed collected |
| Hams Bay | Mahogany hybrid planted in 1969 |
| Sion Farm | *Cedrela* planted in 1955; line planting of mahogany in old cane field; sawmill installed in 1955; hot-cold bath for treatment of fence posts |
| Sion Hill | Logging of hardwoods including mahogany in 1967 |
| Lower Love | Nursery site in 1972 |
| Mahogany Road | Roadside tree care in 1959 |
| Manning Bay | Experimental seeding of mahogany |
| Mt. Victory | Field crews clean sugar factory ruins |
| Spring Garden | Hybrid mahogany planted in 1961 |
| Thomas | Logging of small-leaf mahogany; charcoaling operations; post-peeler operation in 1960; Alaska mill operation in early 1960s; fence-post treatment |
| St. Croix roadsides | Nursery seedlings distributed for roadside planting on island |

Sources: Briscoe and Nobles 1962, 1966; Geary 1969; Geary and Nobles 1980; Geary and others 1972; Geary and others 1973; Nobles and Briscoe 1966a, 1966b, 1966c, 1966d; Ward and Lugo 2003; Weaver and Francis 1988; Whitmore 1971, 1978.

Photo courtesy of IITF.

*Bob Nobles surveying seedling production in 1958 at Kings Hill nursery.*

*Juan Muñoz Cortes reviewing results of direct seeding of small-leaf mahogany* (Swietenia mahagoni) *at Estate Cotton Valley in 1961.*

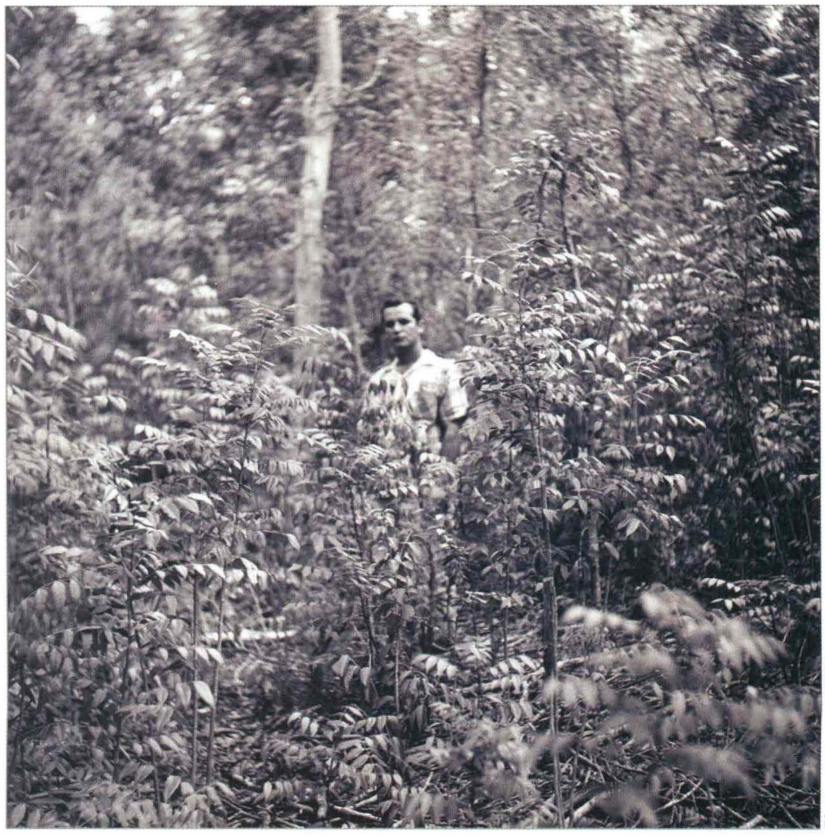


Photo courtesy of IITF.

sometimes forced delays in planting. Moreover, in addition to the experimental work, by 1961 foresters had planted more than 86,000 mahogany and 37,500 teak trees on various sites throughout St. Croix (Anonymous 1962).

## *Forest Service Activities: 1963-2000*

Estate Thomas was partitioned into compartments or blocks to facilitate management, as follows (Ward and others 2002; fig. 3):

- Block A, 9.5 ha, ranging from the northwestern corner south, slightly beyond the middle of the Estate, dominated by small-leaf mahogany
- Block B, 10.3 ha, northeastern corner, extending about nine-tenths of the distance along the northern boundary, dominated by small-leaf mahogany
- Block C, 2.9 ha, extending from the eastern border about one-third the distance westward across the Estate, dominated by small-leaf mahogany, some of which was thinned during the 1960s
- Block D, 5.7 ha, narrow strip ranging from the eastern border westward about three-quarters of the distance across the Estate, planted in teak in the central part; also the site for studies of *Cedrela*, mahogany adaptability, and Pacific Coast mahogany
- Block E, 9.9 ha, running roughly through the middle of the Estate, main site for teak plantings started in 1956; also, the site for studies of lignum-vitae, *Cedrela*, mahogany provenances, plum pudding mahogany, root grafting, and Christmas tree plantings
- Block F, 9.9 ha, an irregular strip running east to west through the southern portion of the Estate, containing small-leaf mahogany
- Block G, 11.5 ha, running along the southern boundary of the Estate, containing *Cedrela*, hybrid mahogany, Chittagong, and previously toona

Compartments A, B, C, F, and 85 percent of G are hilly and dominated by small-leaf mahogany. Compartments D, E, and 15 percent of G are in drainages and are comparatively level, thus favoring experimental plantings. The research carried out at Estate Thomas was previously summarized for the Fifth Annual Urban Forestry Conference held on St. Croix (Ward and others 2002).

### Mahogany Provenance Trials (IITF Research Files 2421)

In 1964 and 1965, researchers sampled natural stands of big-leaf mahogany and Pacific mahogany on 24 sites between Mexico and Panama for variation in wood density (Boone and Chudnoff 1970). The specific gravity of big-leaf mahogany wood averaged 0.62, with a range from 0.57 to 0.68. Comparable figures for Pacific mahogany were an average of 0.76 and a range from 0.67 to 0.89.

Researchers collected seeds at 18 of the aforementioned sites and from a naturalized small-leaf mahogany stand in St. Croix. Subsequently, these seeds were germinated and the seedlings planted in different life zones in Puerto Rico and St. Croix (Geary 1969, Geary and others 1973). The big-leaf mahogany sites included five in Mexico, one each in Guatemala and Honduras, and two each in Nicaragua and Panama; the Pacific mahogany sites included three in Mexico and one each in Guatemala, El Salvador, Nicaragua, and Costa Rica. After germination of seed, the investigators planted the seedlings at 11 sites in Puerto Rico and 2 sites in St. Croix (Estate Thomas and Estate Jealousy) and evaluated their survival and growth several times afterwards. The St. Croix estates contained only 10 of the original provenances; moreover, fire disrupted measurements at Jealousy after 1974. The mahogany seed sources showed differences to varying degrees in the following factors:

- Seed pods (length, diameter, and months of maximum seed ripeness)
- Seedling characteristics (height growth and number of simple and compound leaves per plant)
- Leaf characteristics (leaflet numbers and leaf dimensions)
- Survival after planting on wet and dry sites
- Susceptibility to shoot borer (*Hypisipyla grandella*) attack
- Growth rates of 5- to 6-year-old plants in wet and dry locations

Differences between species were more influential than differences among seed sources for adaptability as a timber species; moreover, planting location was very important. Big-leaf mahogany was recommended for plantings in the subtropical moist and wet forest life zones, but only on a limited scale because of problems with weeds and the shoot borer (Geary and

Photo courtesy of Frank H. Wadsworth.

*A fire at Jealousy Estate prematurely ended data collection for the mahogany provenance trial during the mid-1970s.*

others 1973). Hybrid mahogany was suggested for the subtropical dry forest life zone and in transition areas to the subtropical moist forest life zone, both of which are common on St. Croix.

In 1990, about 4 months after the passage of Hurricane Hugo, foresters assessed damage on three of the plantation sites in the provenance trial, including one at Estate Thomas (Francis and Alemañy 2003). The small-leaf mahogany and the northern sources of big-leaf mahogany were those most resistant to storm damage. These provenances grow naturally in the principal hurricane belt—the Caribbean and the east coast of Mexico and Central America through Guatemala. In contrast, the southern sources of big-leaf mahogany and Pacific mahogany showed the greatest storm impacts.

The most recent analysis of the mahogany provenance study assessed the three species planted at 14 sites, varying from dry to wet, in Puerto Rico and at Estate Thomas (Ward and Lugo 2003). The factors evaluated were the relative amounts of environmental and genetic variation in growth and size traits, survival, and insect susceptibility; the segregation of genetic variation among species and among and within populations; and the change of provenance and species characteristics across different environments. The analyses yielded numerous observations, among them:

- Mahogany had about 10 times more genetic variation among species than among provenances
- For big-leaf mahogany, 79 percent of the mean estimated variance was linked with the environment, 11 percent with genetics, and 8 percent with interaction between them; comparable values for Pacific mahogany were 41, 15, and 29 percent, respectively.
- Big-leaf mahogany always showed the greatest mean growth (height, d.b.h., and volume) by year.
- The three species and several populations showed distinct responses in survival and growth when exposed to different life zones and soil types.
- Provenances became genetically more distinct with increasing distance among source populations.

## Hybrid Mahogany

Big-leaf and small-leaf mahogany hybridize on St. Croix where those species grow in proximity. In 1960, foresters replicated a trial of small-leaf, big-leaf, and hybrid mahogany at 11 sites on St. Croix. The sites ranged from 10 to 180 m in elevation and from 750 to 1350 mm/year in rainfall. Hybrid mahogany seedlings (*S. mahagoni* and *S. macrophylla*, with each as a mother tree) grew faster the first 2 years than small-leaf mahogany, which in turn grew faster than big-leaf mahogany on seven of the eight sites reported (Betzy's Jewel, Bodkins, Bugbyhole, Cane Bay, Hams Bluff, Bethlehem Upper New Works, Sion Hill, and Estate Thomas) (Briscoe and Nobles 1962). From ages 4 through 7 years, however, the height growth of mahogany hybrids and big-leaf mahogany exceeded that of small-leaf mahogany (Nobles and Briscoe 1966a). After 10 years, only three sites (Betzy's Jewel, Bodkins, and Bethlehem Upper New Works) had enough trees for analyses because many had been lost through drought. At those sites, the hybrid survived better and grew more rapidly than either parent; differences, however, were not significant (Geary and others 1972). The hybrid mahogany appeared to combine the drought resistance and wood quality of small-leaf mahogany with the faster growth of big-leaf mahogany. It also had better form than small-leaf mahogany and appeared to be more resistant to shoot-borer damage than big-leaf mahogany (Whitmore and Hinojosa 1977). Currently, despite problems with drought, the hybrid is recommended for planting on St. Croix except on very dry sites.

Hybrid mahogany plantations established at Bodkins in 1956 and Sion Farm in 1971 were sampled in 1986 (Weaver and Francis 1988). After at least one thinning, the Sion Farm plantings had an average basal area of 20.2 $m^2$/ha compared to 32.0 $m^2$/ha at Bodkins. Mean annual d.b.h. growth was 1.14 cm/year at Sion Farm and 0.77 cm/year at Bodkins. Trees in the dominant crown class at Sion Farm and Bodkins grew about 1.9 and 1.3 times faster, respectively, than the average for all trees combined. These growth rates are impressive for the generally dry conditions of St. Croix.

Pacific mahogany and small-leaf mahogany (*S. humilis* x *mahagoni*) hybridize on St. Croix where the two species are planted in proximity; the hybrid

*Mahogany* (Swietenia macrophylla x mahagoni). *Lambert Frederiksen examining successful 18-year-old hybrid mahogany plantation at Bodkins in December 1976.*

Photo courtesy of Frank H. Wadsworth.

is intermediate in height growth and seed weight (Whitmore and Hinojosa 1977). Researchers have not observed this hybrid previously because the natural ranges of both species are distinct and distant from each other.

## Other Formal Mahogany Studies

Other formal studies were conducted with mahogany at Estate Thomas. These include:

- Root pruning of small-leaf and big-leaf mahogany nursery stock
- Thinning by peeling and frilling unwanted competition
- Planting plum pudding mahogany
- Planting Pacific mahogany

On St. Croix, potted mahogany seedlings are required to ensure survival in the field because dry field conditions often occur at the time of planting. Seedlings stored in rigid containers for several months before planting often develop a mass of circling roots. Root pruning of nursery stock, both small-leaf mahogany (at 7, 17, and 30 months) and big-leaf mahogany (at 7 and 17 months), did not affect survival or growth of the seedlings after outplanting (Nobles and Briscoe 1966b).

Thinning promotes the growth of small-leaf mahogany crop trees. The thinning of unwanted trees using arboricides, however, can kill nearby crop trees since intraspecific root grafts move the poison. Another alternative, the peeling and frilling of unwanted small-leaf mahogany, killed about 70 percent of the treated trees within 15 months (Nobles and Briscoe 1966c).

In 1960, foresters established a plantation of plum pudding mahogany (small-leaf mahogany with an attractive grain) from seed at Estate Thomas. By 1986, the stand had a basal area of 25 $m^2$/ha, averaging 0.84 cm/year in d.b.h. growth (Weaver and Francis 1988). The dominant trees within the stand had grown an average of 1.27 cm/year in d.b.h..

In 1961, foresters planted Pacific mahogany at Estate Thomas. By 1986, the plantation was comparatively dense, with an average basal area of 39 $m^2$/ha (Weaver and Francis 1988). The mean annual rate of d.b.h. increment was 0.81 cm/year with the dominants averaging 1.50 cm/year.

## *Cedrela* Provenance Trials (IITF Research Files 2450)

In 1969, seeds from eight provenances of *Cedrela* (*C. odorata*, *C. mexicana*, and *C. tubiflora*) were planted in adaptability trials in Puerto Rico and St. Croix (Whitmore 1971). The provenances came from Misiones, Argentina; two unnamed sites in Belize; Guanacaste and Turrialba, Costa Rica; Cuba (a plantation); Enfield, Jamaica; and Campeche, Mexico.

In both Puerto Rico and St. Croix, the Guanacaste provenance showed superior overall performance for the nursery phase, including height growth. The poorest height growth in Puerto Rico was by the Argentine provenance and in St. Croix by the Cuban provenance. Performance, based on a combination of factors including height, d.b.h., degree of shoot-borer attack, mortality, and number of branches, varied among provenances at the time of outplanting.

Three years after outplanting at two sites in Puerto Rico and three sites on St. Croix (Estate Thomas, Bog of Allen, and Hams Bluff), the best height growth was attained by the Turrialba provenance in Puerto Rico and the Belizian provenance in St. Croix (Whitmore 1978). The Argentine provenance in Puerto Rico and the Jamaican provenance on St. Croix had the poorest height growth. The correlation between height growth after 1 year in the nursery and height growth 3 years after outplanting was very low. In conclusion, none of the provenances grew satisfactorily on any of the sites, and until the best sites are known for the species, provenance trials will only show growth under limiting conditions. In 1986, the remaining *Cedrela* trials at Estate Thomas and Hams Bluff were remeasured (Weaver and Francis 1988). Again, on St. Croix, the best height growth was attained by the Belizian provenance at Estate Thomas and the poorest by the Jamaican provenance at Hams Bluff.

## Teak Provenance Trial (IITF Research Files 2473)

The teak planted in Puerto Rico, and subsequently introduced to St. Croix, originated in Burma and arrived via Trinidad (Keogh 1979). By 1960, 35,000 seedling stumps and potted seedlings had been planted on 14 ha in St. Croix (Nobles 1960). In 1956, mowing the understory beneath young teak in the central drainage at Estate Thomas improved accessibility and reduced the threat of fire, but did not affect either

d.b.h. or height growth (Nobles and Briscoe 1966c). This same plantation was pruned after 8 to 10 years to improve log quality (Briscoe and Nobles 1966). The season of pruning influenced later branching; pruning after leaf flush reduced adventitious branching by one-half in comparison to other dates. Among 50 trees in this plantation sampled in 1986 to determine growth rates, the mean basal area was 15.3 $m^2$/ha, and the mean volume was 116 $m^3$/ha (Weaver and Francis 1988). The mean height growth averaged 0.51 m/year and mean d.b.h. growth 0.76 cm/year.

A trial was conducted to determine if any of 16 teak seed provenances—11 from India, 3 from Thailand, and 1 apiece from Indonesia and Ghana—grew better than Burmese teak, using seed from the Danish/FAO Forest Tree Seed Centre. Three sites were planted in 1975 and 1976, two in Puerto Rico and one at Bodkins in St. Croix. The Bodkins site had 12 replications of 6 provenances [Sabana, Puerto Rico (originally from Burma); two from India; and one each from Indonesia, Thailand, and Ghana]. By 1986, an Indian provenance showed the most rapid growth with a mean d.b.h. of 13.8 cm and mean height of 10.5 m (Weaver and Francis 1988). Neither Estate Thomas, with shallow soils, nor Bodkins was a good site for teak (Ward and others 2002). Also, recent hurricanes heavily impacted teak, notably on sites with shallow soils like Estate Thomas.

## Species Adaptability Trials (IITF Research Files 2394)

Between 1961 and 1966, bare-root seedlings of 14 exotic tree species were tested at 7 sites (Annaly Bay, Betzy's Jewel, Estate Thomas, Hams Bluff, Judith Fancy, Kings Hill, and Solitude) on St. Croix for their suitability as fast-growing timber and urban trees (Geary and Nobles 1980). The five conifers were *Pinus caribaea* v. *hondurensis*, *P. caribaea* v. *bahamensis*, *P. montezuma*, *Cunninghamia lanceolata*, and *Callistris hugellii*. The nine hardwood species were *S. humilis*., *S. macrophylla* x *mahagoni*, *S. mahagoni*, *S. macrophylla*, *Cedrela odorata*, *Roseodendron donnell-smithii*, *Anthocephalus chinensis*, *Terminalia superba*, and *Chukrasia tabularis*. Despite variation in treatments, replications, and length of measurements, it was observed that:

- None of the conifers was satisfactory for planting on St. Croix.
- *S. macrophylla* x *mahagoni* hybrid grew well.
- *S. mahagoni* adapted well but grew slowly.
- *Cedrela odorata* and *Chukrasia tabularis* showed enough potential to justify more trials.
- *S. macrophylla* and *S. humilis* were of interest for hybridizing with *S. mahagoni*.
- *R. donell-smithii* was questionable because of slow growth.
- *A. chinensis* and *T. superba* were unsuitable.

## Other Plantings

In 1969, lignum-vitae, listed as endangered in the Virgin Islands (Gibney and others 1991; see endnotes), was planted in block E of Estate Thomas. After 23 years, survivors averaged 2.9 cm in d.b.h. (Francis 2000a). In 1971, foresters planted *Toona ciliata* in block G, but most of the trees were lost soon after in a fire. In 1972 and 1973, they added *Cedrela odorata* in block G (Ward and others 2002).

Lignum-vitae (Guaicum officinale). The 1969 planting in Block E of Estate Thomas shows the potential for restoration of this rare native species on St. Croix.

Photo courtesy of Peter L. Weaver.

## Current Situation

Five hurricanes between 1989 and 1999 had a major impact on St. Croix's structures, investments, and tourism, and on the forest plantations at Estate Thomas. Perhaps no decade in St. Croix's short history of human occupation has shown so vividly the tenuous nature of commercial forestry production.

The teak plantings in block D are largely destroyed (Ward and others 2002). Virtually all of the *Cedrela* provenance trial in block E is also gone, but *Cedrela* plantings remain in block G. Secondary trees and shrubs cover Blocks D and E, the site of the majority of the Estate's plantations. Small-leaf mahogany, however, has survived well not only on Estate Thomas but also elsewhere on St. Croix, highlighting its utility for local reforestation. The prime example is the majestic 225-year-old line of trees along Mahogany Road. Few places in the world are capable of growing the world's most esteemed furniture species—small-leaf mahogany—so close to a major tourist market like that of the Virgin Islands. One high-value alternative for Estate Thomas is the sustained production of mahogany for locally produced furniture and handicrafts.

## *Conservation, Education, and Demonstration*

The history of forestry at Estate Thomas spans one-half of a century, yet very few people know the location of Estate Thomas (which is called Sion Farm locally) or the Forest Service's research on the island since the early 1950s. The main objectives of the agency during most of that period were experimental field activities and the study of tree species adaptation and growth. Since the mid-1990s, however, the Forest Service, through its S&PF program, cooperated locally with the private sector. Among stakeholders on St. Croix were the Natural Resources Institute (CANARI); Crucian Gardens; National Park Service; Natural Resources Conservation Service; St. Croix Environmental Association (SEA); St. George Village Botanical Garden; Virgin Islands Department of Agriculture; Virgin Islands Department of Education; Virgin Islands Department of Housing, Parks and Recreation; Virgin Islands Department of Planning and Natural Resources; and UVI Extension Service.

*Mahogany* (Swietenia mahagoni). *These majestic trees shading Mahogany Road have survived numerous storms since their planting by the Danish circa 1775.*

Photo courtesy of Peter L. Weaver.

## State and Private Forestry Documents

Population growth and urban sprawl cause erratic development and place pressures on existing forestland. The principal value of St. Croix's secondary forests and woodlands today is for wildlife habitat, recreation, soil and watershed protection, and esthetics, rather than for timber production. As early as 1976, a comprehensive problem analysis on needed forestry research in the Virgin Islands called for town forestry to benefit both residents and tourists (Somberg 1976). The report, developed through the Virgin Islands Agricultural Experiment Station in cooperation with the IITF, suggested tree species for urban environments and research on several topics including the mahogany hybrid, forest recreation, watershed protection, wildlife, and the introduction of a traditional Christmas conifer. During the past decade, the staff of the S&PF program wrote the following documents:

- **Estate Thomas: Analysis of the management situation (AMS) (1997)**—The unpublished AMS document contains a site description and an overview of resource management (Rivera 1997, see endnotes). It briefly reviews management presence, rights-of-way, law enforcement, and vegetation management. Other topics include the physical environment (geology and topography, soils, water, and climate), the biological environment (vegetation and wildlife), and the social and economic environment (recreation, interpretation and environmental education, wilderness, roads and facilities, research and demonstration, heritage, and scenery resources).
- **Forest stewardship management plans (2000)**—Forest stewardship plans developed for Estate Thomas and with private landowners elsewhere on St. Croix outline management practices for forests and related resources. The goals are to maintain the lands in a productive condition and increase their economic and environmental value. Each stewardship plan briefly describes forest location and history; soils; water; historical, cultural, and archeological sites; esthetic quality; wildlife; threatened and endangered species; recreation; timber and forest health; management objectives; forest blocks (for management purposes); and management objectives with a timetable.
- **Comprehensive Strategic Plan for Urban and Community Forestry in the Virgin Islands (2001-05)**—Partner agencies and groups working on matters of conservation and protection of natural resources in the Virgin Islands include the Virgin Islands Department of Agriculture, and especially the Forestry—Soil and Water Conservation Branch; the Virgin Islands Urban and Community Forestry Council; the Forest Service; and the Southern Group of State Foresters (Virgin Islands Department of Agriculture, Forestry—Soil and Water Conservation Branch and Virgin Islands Urban Forestry Council 2001). Their goals include the development of a private sector concerned about forest resources, the enhancement of interagency cooperation within the Virgin Islands government, the encouragement of tree planting and protection, and fostering research on tropical trees. Forestry-related needs and issues of the Virgin Islands were identified at a meeting of the Urban Forestry Council members. They were, in order of priority, education and promotion for planting indigenous trees; protection of trees on construction sites; selection of appropriate trees for planting under power lines; protection against soil erosion using trees; proper planting techniques in urban areas; evaluation of the condition of street trees; education for the public and managers on the benefits and proper maintenance of trees; development and distribution of forestry materials for education and information purposes; and selection of trees for use in government planting efforts.

## State and Private Management Practices

The major S&PF management practices during the past 15 years aimed at forest protection and tree use. In preparation for the pink mealy bug infestation of the early 1990s, the S&PF staff alerted agencies and residents on St. Croix about the insect's damaging effects and protective measures as it gradually spread northward from Grenada. At the same time, the staff developed cooperative activities with the Virgin Islands Fire Department to protect against fires.

After Hurricane Marilyn in 1995, the S&PF staff authorized local wood users to salvage damaged teak and mahogany trees for the use of local artisans and prospective clients. At the moment, the only planned harvest is the transplanting of small-leaf mahogany

trees from Estate Thomas to urban locations. This activity currently involves root pruning in the field (digging a trench around trees about 2 m from the trunk) and periodic irrigation. Once transplanted to urban sites, the trees will be irrigated for a period.

A more diversified presence by the Forest Service at Estate Thomas would benefit both residents and visitors to St. Croix. An approved management plan needs sufficient funding to implement conservation and educational programs. The plan should involve all individuals and groups with an interest in environmental issues on St. Croix: major government agencies, NGOs, the universities, the island's high school system, environmental groups, and the general public. Staff members should maintain records of school projects, field studies, research by IITF cooperators, the harvest of small-leaf mahogany for artisans, and the use of the Estate for special events.

## Highlighting Demonstration and Management

The cultivation of native tree species to improve wildlife habitat and enrich the forests of Estate Thomas is a project that would capture local interest. Among the best candidates for planting are *Bucida buceras*, *Calophyllum calaba*, *Clusia rosea*, *Guaiacum officinale*, *Hymenaea courbaril*, *Pimenta racemosa*, *Roystonea borinquena*, and *Zanthoxylum flavum*. Other activities should include:

- Highlighting the unique role of Estate Thomas in the history of St. Croix—one of forestry research including plantations, adaptability studies, species trials, and provenance work using seeds from throughout the world
- Demonstrating the current importance of Estate Thomas as a multiple-purpose forest management site to residents of St. Croix
- Marking boundaries and placing signs along roads
- Implementing cultural resource surveys before road construction or recreational developments
- Placing interpretative signs at all important historical, cultural, and study sites
- Managing small-leaf mahogany timber for demonstration and educational purposes, including thinning, and selective harvest of small amounts of high-value timber for the production of furniture and handicrafts by the island's artisans (Francis 1995)
- Pruning and transplanting small-leaf mahogany for island shade-tree projects such as Market Square (Esham 2004)
- Demonstrating the role of hurricanes in forest management and salvaging dead timber after major storms or hurricanes
- Showing plantation management techniques where feasible
- Growing more native plants in a small demonstration nursery for sale to local landowners
- Increasing the representation of native plants, particularly those that are rare on St. Croix
- Improving wildlife habitat at Estate Thomas
- Maintaining the Estate (i.e., routine surveillance, law enforcement, refuse disposal, and fire patrol, particularly during prolonged droughts)

## Maintaining the Forestry Research Tradition

The Forest Service purchased Estate Thomas for research in the dry tropics, and that has been the major use of the property for 50 years. Most likely research on establishing forest plantations for timber production will play a smaller role in the future. However, the measurement of existing long-term studies (for example, plantings of mahogany, *Cedrela*, and lignum-vitae) should be continued where feasible (Ward and others 2002). Research objectives that will become more important are:

- The germination requirements and early growth of native tree species and methods for their establishment on degraded sites on Estate Thomas and elsewhere on St. Croix (Daly and Zimmermann 2002, 2004)
- Autecological studies of forest trees and shrubs, particularly of rare native species
- Changes in species composition (succession) as the plantations mature and native species enter the stands
- Species-site relationships, and the importance of soil variation, especially for urban trees
- Hurricane damage assessment and posthurricane recovery
- The competition of invasive species with native pioneers in succession
- Adaptability and provenance studies on a limited scale for special purposes

- Periodic inventories and monitoring of permanent plots to assess changes in forest structure and composition at Estate Thomas and elsewhere in the Virgin Islands
- Assessment and monitoring of wildlife species
- Habitat requirements for declining or threatened wildlife species
- Archeological surveys associated with the past occupation of the Estate Thomas settlement

## Recreational Opportunities

Recreational needs will increase as the population of St. Croix continues to grow. Several areas at Estate Thomas could be developed for picnics and outdoor entertainment. At least two high points offer vistas of the island. Lookout or walkup towers (fig. 3) could provide views of the Christiansted harbor and the southern shoreline of St. Croix. Interpretative signs or brochures for hiking trials could explain past research activities and forest history. Passive recreation such as birdwatching and hiking are compatible with forest monitoring.

## School Educational Programs

Estate Thomas offers excellent field sites to host school science programs. In April 2004, a permanent demonstration plot was established for long-term ecological research (LTER) near the main gate on Route 811 (fig. 3, site 12). The history of the plot is known since it was an experimental area with large Chittagong and mahogany trees. Several of the canopy trees, however, are either damaged or dying; moreover, the lower canopy and understory contains about 15 species of trees, including some exotics. At the moment, the stand is changing from a managed plantation to natural forest. Local high school students could monitor the flora and fauna on the plot during field studies.

While monitoring the plot, students would learn forestry techniques. They could measure d.b.h., height, and crown features and calculate typical stand parameters like basal areas, estimated volumes, and possibly biomass. Students could also determine tree growth, the response of vegetation to major storms or hurricanes, and successional changes in forest structure and species composition as the vegetation changes over time. Future thinnings in other parts of the forest could show the importance of forest

*Chittagong* (Chukrasia tabularis). *The 1968 Chittagong plantation in Block G of Estate Thomas, with an understory of native tree species, is the current site for the student plot.*


Photo courtesy of Peter L. Weaver.

management. Other educational opportunities at Estate Thomas include:

- Developing interpretative signs for important sites (e.g., historical, cultural, botanical, and research sites, and scenic views)
- Explaining the value of tree species (e.g., as forage for deer, in landscaping and gardening, medicinal uses, or to attract bird species to home gardens)

## *Other Protected Terrestrial Areas on St. Croix*

The U.S. Government, the Virgin Islands government, NGOs, and private individuals protect and manage natural areas on St. Croix and offshore islands (fig. 6). Much of the following information was derived from undated brochures—information that is available to the public without charge.

### Federal Government Properties

The Forest Service owns 59.7 ha at Estate Thomas. In addition, two other Federal Government entities manage large properties on St. Croix: the U.S. Department of the Interior Fish and Wildlife Service and the U.S. Department of the Interior Park Service.

**U.S. Fish and Wildlife Service**—On St. Croix, the U.S. Fish and Wildlife Service manages two properties totaling 138 ha, Green Cay and Sandy Point (table 9; fig. 1). Designated in 1977, Green Cay protects the largest remaining natural population of the endemic and endangered St. Croix ground lizard (*Ameiva polops*), extirpated on the main island near Frederiksted in the early 1970s (Philibosian and Yntema 1976). The subtropical dry forest on Green Cay is prime bird nesting habitat and contains numerous cacti. A kitchen midden, evident on the east side, indicates previous use by Indians (Damman and Nellis 1992). Because of the fragile nature of the habitat and possible disturbance to the wildlife, the refuge remains closed to the public. The ground lizard was also introduced onto Buck Island but was later eliminated after mongoose trapping ceased (Philibosian and Yntema 1976). The only other sites where the ground lizard still occurs are Protestant Cay and Ruth Cay (McNair 2003, McNair and Coles 2003). Protestant Cay is a 1.6-ha island reaching 12 m in elevation in Christiansted harbor. The sparsely vegetated island is occupied by a hotel and amenities, and the former residence of the harbor pilot. On the south coast, Ruth Cay contains grasses, sedges, and salt-tolerant woody plants (Damman and Nellis 1992).

Figure 6—Map of major public areas and private protected properties on St. Croix, 2005 (locations are approximate, lacking ground proof).

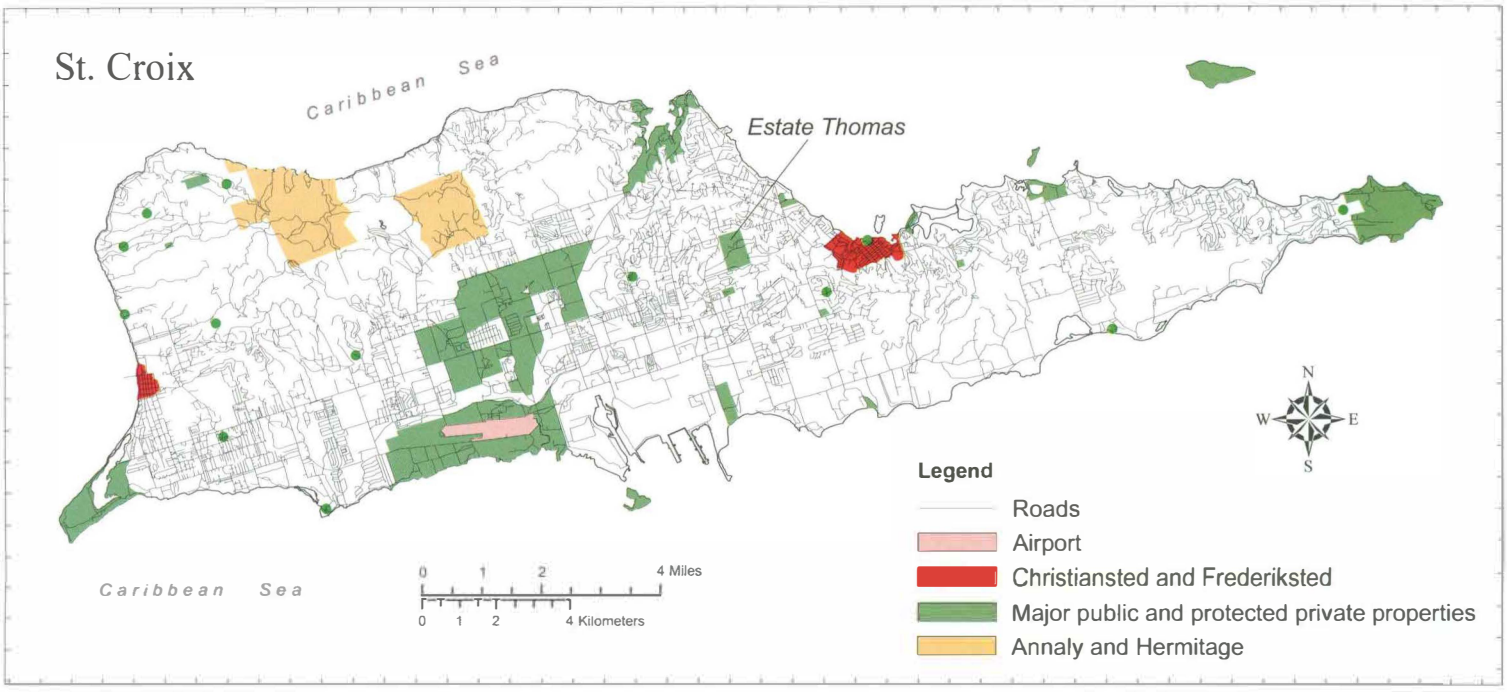


**Table 9—Major public and private properties on St. Croix and surrounding offshore islands managed as protected areas, including recreational areas, or with potential for such use[a]**

| Entity and property name | Date(s) acquired | Area | Elevation |
|---|---|---|---|
| | | *(ha)* | *(m)* |
| **Public Lands** | | | |
| USDA Forest Service | | | |
| Estate Thomas | 1963 | 59.7 | 80-135 |
| USDI Fish and Wildlife Service | | | |
| Green Cay | 1977 | 5.5 | 0-19 |
| Sandy Point | 1984 | 132.4 | 0-2 |
| USDI Park Service | | | |
| Buck Island Reef National Monument[b] | 1948-61 | 71.4 | 0-100 |
| Christiansted National Historic Site | 1952 | 2.8 | 0-2 |
| Salt River National Historic Site | 1992 | 411 | 0-75 |
| Sion Ridge area | 1963 | 9 | 60 |
| Virgin Islands government | | | |
| Caledonia and Caledonia Gut | 1981 | 39.1 | 140-190 |
| Creque Dam (plot 1) | 1926? | 2.3 | 100 |
| East Point (Point Udall) | 1938 | 54.4 | 0-120 |
| Estate Adventure Nature Trail[c] | 2004 | 2.5 | 15-25 |
| Estate Great Pond (plots 5 and 6) | 1974 | 5.9 | 0-2 |
| Housing, Parks and Recreation[d] | Various | 160 | Variable |
| Longpoint and Cotton Garden (plots 4 and 5) | 1977 | 69.6 | 1-168 |
| Mahogany Road (marginal trees) | 1775 | NA | ~ 5 |
| Ruth Cay dredge islet | 1960s | 7 | 0-4 |
| Spring Garden (plots 7 and 8) | 1990 | 28.7 | 0-182 |
| University of the Virgin Islands | | | |
| Estate Golden Grove (campus) | 1968-69 | 48.9 | 25-40 |
| Estate Barren Spot wetlands[e] | 1994 | 19 | 0-33 |
| **Private Lands** | | | |
| Nature Conservancy | | | |
| Estate Little Princess | 1990 | 9.9 | 0-20 |
| Jack and Isaac's Bay | 1999 | 122 | 0-198 |
| Hermon Hill (plot 1) | 1995 | 6.6 | 40-50 |
| Long Point Bay (Carlton plot 112) | 1994 | 9.1 | 0-3 |
| Annaly Bay and Hermitage Valley[f] | NA | NA | NA |
| St. Croix Environmental Association | | | |
| Estate Barren Spot (plot 299-A)[g] | 1999 | 0.2 | 30 |
| Estate Prosperity beachfront[h] | NA | 0.1 | 0-2 |
| Southgate Pond properties | 2001-02 | 40.1 | 0-3 |
| St. Croix Landmarks Society | | | |
| Butler Bay Nature Preserve | 1985-92 | 91 | 0-NA |
| Estate Little La Grange | 1976 | NA | NA |
| Estate Mt. Washington Bird Sanctuary | 1984 | 8.8 | NA |
| Estate Whim | 1947 | 4.8 | 25-35 |
| St. George Village Botanical Garden | 1973 | 6.5 | 40-50 |

NA = data currently not available or not precisely known.

[a] Elevations and plot numbers from the Cadastral Office (records and deeds), 7-8 King Street, Christiansted, St. Croix. Elevations interpolated from map [(CH2M Hill Southeast, Inc. (n.d.))]. The Virgin Islands government owns additional properties (Property and Procurement Office, Christiansted, St. Croix).

[b] In addition, about 7627 ha of protected waters, including reefs, surround Buck Island, so the total area of the national monument is nearly 7700 ha.

[c] The Estate Adventure Nature Trail is 1.2 km long by 20 m wide.

[d] Forty properties throughout island (see details in appendix B).

[e] Also called Billy French Ponds (plots 1a, 2, 3, and 4)

[f] The Nature Conservancy is considering the expansion of protected areas on St. Croix through the Virgin Islands Forest Legacy Program (fig. 6). Currently, precise areal information is not available.

[g] Bat tower.

[h] Steinman property (parcel 2 ad).

In 1984, the U.S. Government purchased Sandy Point to protect the largest turtle nesting beach in the country (Earsom and others 2004; table 9). With an abundance of conch middens indicating previous use by Indians, the site is on the National Register of Historic Places. A continuous beach > 3 km long without a fringing reef provides excellent conditions and nesting habitat for leatherback (*Dermochelys conacea*), hawksbill (*Eretmochelys imbricata*), and green (*Chelonia mydas*) sea turtles. Coastal woodland vegetation with 225 plant species grows along the shoreline; permanent and ephemeral salt ponds and fringe mangroves provide habitat and foraging areas for more than 100 species of birds. Management focuses on protecting adult sea turtles and their nests. Local students, community groups, and volunteer researchers help relocate nests dug in areas threatened by sea erosion. At present, the refuge is open to the public on Saturdays and Sundays.

**U.S. National Park Service**—The U.S. National Park Service manages four properties totaling > 480 ha on St. Croix: Buck Island Reef National Monument, Christiansted National Historic Site, Salt River National Historic Site, and the Sion Ridge area (table 9). The Virgin Islands government gained control of Buck Island in 1936 and created Buck Island Park in 1948. In 1961, the Virgin Islands legislature authorized the transfer of the island to the Park Service as a national monument. Buck Island, about 2.7 km north of St. Croix's eastern coast, rises to 100 m along a ridge running east to west (Woodbury and Little 1976; fig. 1). The topography of Buck Island varies, with rocky cliffs of volcanic origin to the east and coastal plains bordering stretches of sandy beach to the west (Small 1982). A salt pond, 120 m long and 45 m wide, lies along the southwestern shore.

A survey of Buck Island's subtropical dry forest made during four trips from 1966 to 1970 disclosed 228 species of seed plants in 171 genera and 63 families; 17 of the tallied species were introduced (Woodbury and Little 1976). The main vegetation

*Sandy Point. The U.S. Fish and Wildlife Service protects the southwestern tip of St. Croix, excellent nesting habitat for leatherneck* (Dermochelys coriacea), *hawksbill* (Eretmochelys imbricata), *and green* (Chelonia mydas) *sea turtles.*

Photo courtesy of U.S. Fish and Wildlife Service.

Photo courtesy of Peter L. Weaver.

*Buck Island. The U.S. Park Service manages the island and surrounding waters totaling about 7700 ha, where a snorkeling trail through the coral reef is a favorite tourist attraction.*

type was thorn woodland frequently grading into thorn scrub (Forman 1974). The most common families were Leguminosae, 28 species; Gramineae, 22; and Euphorbiaceae, 17 species. The researchers recorded one orchid, *Epidendrum brittonianum* A.D. Hawkes) but no ferns. The stinging bush (*Malphigia pallens* Small) is endemic to St. Croix, rare, and endangered (Little and Woodbury 1980). Moreover, because of its stinging hairs, it could be targeted for eradication on private land. Two other species, manjack (*Cordia rickserkeri* Millsp.) and adormidera (*Croton rigidus* Muell. Arg. Britton), are endemic to Puerto Rico and the Virgin Islands. Absent in the survey, lignum-vitae, valued for its wood and flowers, has been nearly exterminated in the Virgin Islands except where planted (Woodbury and Little 1976). The Dutch originally called Buck Island Pocken-Eyland (Lignum-vitae Island) because that was "the tree with which the island, now an arid waste, was forested" (McGuire 1925, page 147). The lignum-vitae trees were removed to establish a plantation in 1754 (Damman and Nellis 1992). Restoration of this majestic species on the island would seem to be a legitimate management priority.

Colonies of brown pelicans (*Pelicanus occidentalis*) nest in treetops on Buck Island's rocky cliffs (Small 1982). The only mammals on the island are introduced—the tree rat (*Rattus rattus*) and the mongoose. Hawksbill and green turtles have nested on the island regularly since the early 1960s (Seaman and Randall 1962), and leatherbacks were reported in the mid-1970s (Small 1982). The St. Croix ground lizard was introduced to Buck Island in 1968 during a mongoose trapping program (Philibosian and Ruibal 1971). When the program ceased, the ground lizard was extirpated. Three archeological sites exist on Buck Island: an aboriginal site of scientific importance dated between 800 and 1200 A.D., an 18$^{th}$-century homestead, and a late 19$^{th}$- or early 20$^{th}$-century wreck of a ship that was carrying coal (Prokopetz 1976). The sites, which represent prehistoric occupation, the plantation period, and the industrial era, merit protection and interpretation.

In addition to Buck Island, the National Monument has > 7600 ha of coral reefs and ocean. Beginning in 1976, several studies in the surrounding waters

addressed currents and beach erosion, structure and dynamics of the reefs and seagrass communities, abundance and species composition of fishes, and cyclical (seasonal) changes in the growth and population dynamics of various reef organisms. The studies also showed the impacts of human activities and major storms such as Hurricane David and Tropical Storm Frederick on the resources (Gladfelter and Gladfelter 1980; Gladfelter and others 1978, 1979). The studies identified 250 species of benthic algae, 12 phyla of zooplankton, and 127 species of fishes. Buck Island recreation facilities include self-guided underwater trails through the corals, beaches, and a picnic area. Overnight camping is currently prohibited.

The Christiansted National Historic Site, established by Memorandum of Agreement in 1952, consists of six historic buildings. Both Fort Christiansted and the Danish West Indies and Guinea Company Warehouse date to 1749, the Steeple Building to 1753, the Custom House and the Government House to 1830, and the Scale House to 1856. The wharf area, which shows the town's way of life during Danish rule, was an important economic link to Europe, West Africa, the Caribbean, and North America during the 18th and 19th centuries. Downtown Christiansted resembles European court compounds of the 16th century (Copeland 1976). Arcaded commercial buildings protect people from sun and rain (Douglas 1996). Danish arcades typically have shallow arches and extensive brickwork.

The Salt River National Historic Site, on the north central coast of St. Croix 9 km west of Christiansted, is where Columbus landed on November 14, 1493 (table 9; fig. 1). The site, co-managed with the Government of the Virgin Islands, became a U.S. Park Service unit in 1992 (Willocks 1995). In 2004, the Park Service remodeled a building overlooking the shoreline and estuary as a visitors' center.

The diverse natural environment of Salt River has upland terrestrial, estuarine, and marine areas within a small area (Cissel 1998). With the largest remaining mangrove in the Virgin Islands, seagrass beds, a freshwater pond, and a patch of giant ferns (*Acrostichichum danaefolium*), Salt River provides important foraging and nesting habitat for St. Croix's wildlife. Just offshore, a submarine canyon with deep-water corals, caverns, and ledges descends nearly 600 m. Salt River has archeological sites that were occupied by different cultures beginning about A.D. 100. Among them is a ceremonial plaza or ball court, the only one known in the Lesser Antilles, and the famous Cape of the Arrows where Columbus first encountered hostile Caribs. Finally, the Park Service manages the Sion Ridge housing facility only a short distance from Estate Thomas (fig. 1).

## Virgin Islands Government Properties

Public properties in the Virgin Islands divide into four major categories:

- Individual areas managed for environmental values (parts of estates or protected areas)
- Properties serviced by Virgin Islands Housing, Parks, and Recreation (appendix B)
- Properties under UVI and the Virgin Islands Department of Agriculture
- Other lands (e.g., the airport) with various uses

**Protected Parcels**—The Virgin Islands government currently owns and manages parcels on several estates as protected areas (table 9). Creque Dam, built in 1926 to provide water to Frederiksted, has a drainage area of about 160 ha (Imsand and Philibosian 1987). The surrounding secondary vegetation, sometimes called rain forest, has some of the tallest trees on the island. The shaded road often provides a glimpse of white-tailed deer in the surrounding forest. The nearby Estates of Caledonia, including the Caledonia gut with a waterfall of 15 m after heavy rains and Spring Garden (plot 8), are highly desirable for wildlife protection. Also close by is Mahogany Road with its centenarian mahogany trees.

East Point (Point Udall) contains the "easternmost point in the United States" according to a sign at the site. It is bordered by other protected areas belonging to the government, such as Estates Longpoint and Cotton Garden, and by properties belonging to the Nature Conservancy. These lands, both public and private, form a large block of terrain characterized by uplands in subtropical dry forest and by sandy shoreline used as nesting sites by sea turtles. Also under the government are small parcels of wetlands at Estate Great Pond and the islet Ruth Cay. Ruth Cay was formed in the mid-1960s when dredge spoils from the Krause Lagoon were dumped in shallow waters south of the Hess Oil Refinery.

Photo courtesy of Peter L. Weaver.

*Creque Dam. Built in 1926 to supply water to Frederiksted, the dam is surrounded by what the Crucians call rain forest.*

*Subtropical dry forest. The eastern tip of St. Croix, or East End, contains a favorite ornamental, the Turk's cap cactus* (Melocactus intortus).

Photo courtesy of Frank H. Wadsworth.

The Estate Adventure Nature Trail parallels a dry streambed that separates Estate Adventure from the UVI campus in Golden Grove. The trail runs for 1.2 km from the old Danish bridge on Centerline Road to the ruins of a sugar mill. The bridge was built in 1910 from locally cut coral and bricks. Three footbridges, a boardwalk, and log stairs lead visitors past native and exotic flora labeled and described in a brochure.

The areas known as the St. Croix rain forest are actually isolated patches of semi-evergreen forest (Forman 1974) within the subtropical moist forest life zone of the northwestern hills. The most notable examples are the government-owned reservoir known as Creque Dam (table 9) and privately owned ravines, or guts, along the North Shore Road. Among the tallest trees growing in these patches are ceiba [*Ceiba pentandra* (L.) Gaertn.], mango (*Mangifera indica* L.), and mammee-apple (*Mammea americana* L.).

**Virgin Islands Housing, Parks, and Recreation**—Virgin Islands Housing, Parks, and Recreation manages about 163 ha including waterfront property and secondary vegetation for aquatic activities (24 percent), passive recreation (8 percent), sports (16 percent), and other purposes (52 percent) (appendix B). All but 2 of the 40 public areas managed by the local government are < 10 ha in size. The two largest areas, Cramer's Park and the old Fairleigh Dickinson University property, account for one-half of the total area under management.

**University of the Virgin Islands and the Virgin Islands Department of Agriculture**—UVI occupies nearly 50 ha of land on Estate Golden Grove, most of which is reserved for current and future use of the university. UVI also owns about 20 ha of coastal wetlands at Estate Barren Spot, including Billy French Ponds, just east of the Hess Oil Refinery on the south shore. The other extensive government-owned properties occupy areas northwest and west of the Hess Oil Refinery (fig. 1). These include the lands under the Virgin Islands Department of Agriculture and the Henry E. Rohlsen Airport, as well as parts of adjacent estates.

## Nongovernmental Organizations

NGOs manage several protected areas on St. Croix. The Nature Conservancy operates internationally, and the SEA, the St. Croix Landmarks Society, and the St. George Village Botanical Garden work locally.

*Cramer's Park. One of the largest of 40 public areas under the Virgin Islands Housing, Parks, and Recreation Department, the park is at the eastern end of St. Croix near Point Udall.*

Photo courtesy of Peter L. Weaver.

**The Nature Conservancy**—The mission of the Nature Conservancy is to protect natural communities and their flora and fauna. Currently, the Conservancy holds four properties on St. Croix totaling about 150 ha (table 9; fig. 1). Since 1990, the Conservancy offices have been at Estate Little Princess, a site listed on the National Register of Historic Places, with a restored great house and surrounding grounds. Also, the Conservancy has adopted two conservation measures to lessen environmental impacts and for demonstration to visitors: a wastewater pond recycles water for irrigation of the estate's grounds, and solar panels generate the electricity used at the site. Cooperators have also initiated studies to restore the estate's coastal xeric forest and mangrove.

The Nature Conservancy also manages Jack and Isaac's Bay at the eastern end of St. Croix (Valiulis 2003, see endnotes). A network of hiking trails threads the steep slopes, which are covered with xeric vegetation of four main types: shrubland, woodland, forest, and herbaceous. Surveys have recorded three threatened plant species: the Sandy Point orchid (*Psychilis macconelliae*), the Turk's Cap cactus (*M. intortus*), and Moujean tea (*Nashia inauguensis*). Wildlife surveys revealed 31 bird species and 3 reptiles. Two species of sea turtles—the threatened green turtle and the endangered hawksbill turtle—nest on the estate's sandy beaches. The Conservancy holds two other small properties: Long Point on the southern coast and a small pond and adjacent land on Herman Hill. The Conservancy has also identified properties throughout St. Croix that should become part of the Virgin Islands Forest Legacy Program, among them two large parcels of nearly 900 ha at Annaly Bay and Hermitage Valley (Nature Conservancy 2003, see endnotes).

**St. Croix Environmental Association**—SEA, formed in 1986, currently manages three properties on St. Croix, the largest, at Southgate Pond, covering 40 ha (table 9; fig. 1). The Southgate property contains a large pond, beach habitat, littoral woodland and scrub, and mangrove woodland (Gladfelter and Gladfelter 2004b). Southgate is a premier birding site where 113 species have been recorded (Gladfelter and Gladfelter 2004a). Of that number, 60 percent are water birds, and 39 have restricted ranges in the United States.

*Estate Little Princess. The recently restored estate, listed on the National Register of Historic Places, serves as the main office of The Nature Conservancy on St. Croix.*

Photo courtesy of Peter L. Weaver.

Photo courtesy of Peter L. Weaver.

Southgate Pond. The St. Croix Environmental Association manages the pond, on the north coast east of Christiansted, as a premier birding site.

After Hurricane Hugo in 1989, the association initiated the ReLeaf program to provide trees for posthurricane planting; later, the program expanded to provide trees for mangrove restoration and for educational projects in schools (Daly 2004). SEA also drafted environmental science curricula for grades 4 through 6 on St. Croix. Other SEA properties include a bat tower on Estate Barren Spot north of the oil refinery and beachfront property on Estate Prosperity north of Frederiksted.

**St. Croix Landmarks Society**—The Landmarks Society, a nonprofit educational organization, traces its origin to 1948 when the original members met to discuss the preservation of St. Croix's cultural heritage (Watkins 1998). Since then, the society has restored the Estate Whim great house, built by Danish sugar planters about 1774. Today, it is furnished with antiques acquired from island families; moreover, it has a library and archives with many historical books, maps, documents, family histories, and photographic materials. The 4.8-ha estate grounds display a windmill and typical machinery used to process sugar cane. The Landmarks Society maintains the great house and other buildings as a public museum, under lease from the Virgin Islands government.

The Society manages properties elsewhere on the island (Ayer 1998). Estate Little La Grange along Mahogany Road in western St. Croix opened in 1996 and showcases the life of a Danish farming family during the late 1890s. The house includes typical furnishings, and the grounds contain well-tended gardens, a freshwater aqueduct, and extensive ruins from sugar cane production. Established by deeds of gift, easement, and hunting restrictions, Butler Bay today serves as a nature reserve and bird sanctuary. It contains a dry creek and 15-m waterfall. Apothecary Hall on Company Street in Christiansted is filled with shelving and jars commonly used in the 1800s. The Landmarks Society also serves as custodian for several stewardship properties:

- An ecologically sensitive hillside west of the Carambola Resort Hotel
- 2 ha of land with a plantation house and ruins at Estate Clairmont
- Two rain forest guts
- 600 m of waterfront property and gut on Estate Prospect Hill

Photo courtesy of Peter L. Weaver

*Estate Whim. The St. Croix Landmarks Society manages the restored great house, furnished with antiques, as well as a library and archives with historical books and photographs*

- A dry creek and waterfall at Estate Washington Hill
- Cliffs and a nature trail at Davis Bay

**St. George Village Botanical Garden**—The 6.5-ha St. George Village Botanical Garden, formed by donations of land to the people of St. Croix, is in tract 27 of the Princess Quarter (Kesler 1980; table 9). The garden is a National Historic District in the National Register of Historic Places. After incorporating as a nonprofit organization, the Garden founders held their first annual meeting in 1973. Volunteers manage the garden to conserve native species, preserve the ethnobotanical history of the Virgin Islands, and provide educational programs on horticulture, ecology, and cultural history.

The garden was an Arawak village between A.D. 100 and 900, a Danish sugar plantation from 1733 to 1917, and a cattle ranch from 1930 to 1972. The estate's earliest records, traced to 1751, show that two owners, Morgan Andersen and Lorentz Grundel, and 20 slaves lived on the site (Kesler 1980).

The garden provides a walking tour among many historic structures including the ruins of a sugar mill and rum factory, an old Danish cemetery, a library, and the restored home of the manager of St. George Village. The garden also contains 1,500 species of exotic tropical plants, among them cacti and succulents, and a tropical orchard with fruit trees. The Great Hall, connecting historic buildings constructed from 1848 to 1860, was originally the living quarters of workers' families. Today, these buildings contain a gift shop and offices. The garden nursery sells a wide selection of propagated plants throughout the year.

## Heritage Trail Sites

The Heritage Trail highlights three types of sites in St. Croix: full-service attractions that may be toured, visitation sites with irregular hours and staffs, and points of interest not open to the public (Tyson and others 2000). Among other natural sites and protected areas not mentioned previously are:

- Annaly Bay and Salt Bay, with hiking trails in the subtropical moist forest
- Great Pond along the south shore, southeast of Christiansted
- West End Salt Pond in the southwestern corner of the island

Photo courtesy of Peter L. Weaver.

*St. George Botanical Garden. The small garden is a National Historic District on a site that was first an Arawak village and later a Danish sugar plantation.*

## The Role of Estate Thomas

"Forests are undoubtedly the most important terrestrial habitat in the U.S. Virgin Islands" (Rodrigues 2002, page 84). They support a large number of bird species, and their fragmentation and destruction are the main threats to the island's avifauna. Estate Thomas, by virtue of its relatively large size, affords some assurance of protection for wildlife during and after destructive climatic events such as hurricanes. Moreover, the Estate provides important habitat in the transition area between the dry eastern part of St. Croix and the more humid northwest, a zone that is already highly disturbed and under continuous pressure for urban expansion.

Estate Thomas is the only major public forest in the interior of St. Croix. Twenty-five percent of the island's population lives immediately around the Estate in the congested Sion Farm sub-district (U.S. Department of Commerce 2003; fig. 7). One-quarter

Figure 7—Estate Thomas and surrounding high-population-density areas, including the Sion Farm subdistrict and nearby Christiansted (U.S. Army Corps of Engineers 2004).

Photo courtesy of Frank H. Wadsworth.

*Field day. Local students gather in the teak* (Tectona grandis) *plantation on Estate Thomas in December 1975 for a day of forestry activities.*

of St. Croix's 53,000 inhabitants are 19 years old or younger and represent the age group that could most benefit from hands-on field experience in research and management of natural resources.

The Estate's vegetation, much of it small-leaf mahogany, provides a forest resource amenable to small-scale timber production for high-value end products such as locally produced furniture and handicrafts. The remaining vegetation, a mixture of native and exotic species, furnishes critical wildlife habitat on a densely populated island where one species of snake and one species of lizard have already been extirpated. The Estate could become an outdoor laboratory for residents and visitors interested in forestry research and management of protected areas and the important role of St. Croix in those efforts. Past forestry research on Estate Thomas and elsewhere in St. Croix involved seeds collected from neotropical countries ranging from Mexico to Argentina and imported from Southeast Asia and India. At least one tourist guide cites Estate Thomas as an experimental forest and highlights the plantings of lignum-vitae, teak, and mahogany (Imsand and Philibosian 1987), some of which survive today and will be remeasured in the future.

A dense secondary forest exists on the Estate today because the land has been protected for research during the past 50 years. The Estate's steep terrain, small size (the Estate occupies only 0.27 percent of the island), and lack of historical and archeological sites (see Zube 1968) precluded its development for cultural or historic purposes. Although sugar cane was grown on the Estate, no ruins associated with sugar processing are found there. Piles of rocks are scattered on the hillsides and reflect past land use, which included wood harvesting, livestock grazing, and cultivation. Estate Thomas has survived to become the only forested public property under multiple-use management on St. Croix.

Protected areas on St. Croix emphasize particular uses. The staff at Virgin Islands Housing, Parks, and Recreation manages many small urban properties for sports activities and passive recreation. Other groups

manage large protected areas such as Salt River, Sandy Point, Buck Island, and Jack and Isaac's Bay. These large areas are either coastal, or in the case of Buck Island, offshore and relatively inaccessible to the local population; moreover, management of many of these properties protects wildlife and habitat and therefore restricts access. Estate Thomas is a readily accessible forest, or "bush" in local terms, where residents and tourists could conveniently become more familiar with nature.

Estate Thomas has sufficient infrastructure to implement a diverse environmental program. Bond Road runs approximately through the middle of the Estate before reaching adjacent private properties (fig. 3). Power and telephone lines that parallel the dirt road could be tapped for use. Another 3.7 km of road, currently overgrown and impassable, could easily be cleared for access and hiking trails. One track connects the central Bond Road with the main entrance at the southwestern corner of block G along Route 811, by the first LTER plot for island high school students (fig. 3).

At one time, barbed wire fence enclosed the boundary of the entire estate; today, much of the fence remains but in degraded condition. Also remaining is the foundation of a wood frame office building destroyed by Hurricane Hugo. A 75-m well lined with 10-cm plastic casing is near the west central boundary at about 80 m in elevation (fig. 3). Although the well's water is too high in chlorides for human consumption, it is suitable for livestock. Since most wells on St. Croix are a few meters above sea level, danger from saltwater intrusion is negligible (Cederstrom 1950). Seepage from the surrounding Tertiary limestone is the likely source of sodium chloride, sodium bicarbonate, and other minerals in the well.

The green space provided by Estate Thomas will be vital and valued as the island's population and suburban areas continue to grow. Its central location—near Christiansted, the Agricultural Experiment Station, the university, and the high school—is ideal for demonstration, education, and interpretation in an outdoor setting. These activities are largely unavailable to residents elsewhere on St. Croix. In many ways, Estate Thomas Experimental Forest is like a central park on a portion of St. Croix otherwise saturated with houses, shopping plazas, and roads.

St. Croix is the island where history is treasured, a place people come to from afar to view the ruins of sugar cane plantations and search the archives at Estate Whim for information about their ancestors. Few residents, however, are aware of the role that St. Croix has played in forest research and management. In the past, the Forest Service carried out studies at nearly 30 sites throughout St. Croix, including Estate Thomas (fig. 1). Forest Service research is a unique part of the island's history—one that interpretation should highlight for residents and visitors alike.

## Acknowledgments

Many individuals played a role in the preparation of this report. Robert Nobles was stationed on St. Croix from 1957 to 1967 and Juan Muñoz Cortés in 1961 and 1962. Both worked in Forest Service programs in cooperation with the Virgin Islands Department of Agriculture. Both have contributed to this report, Nobles through his unpublished annual reports and Muñoz Cortés through his early Forest Service experiences and comments regarding the Estate. Also, Eric (Larry) Bough, formerly with the Virgin Islands Agricultural Experiment Station, has generously helped with field orientation and historical information. Frank H. Wadsworth, who initiated the Estate Thomas research program, helped with lesser known details and reviewed the manuscript. For the section on Estate Thomas and Sion Farm, George Tyson, a researcher and author based on St. Croix, provided detailed background information from three main sources: U.S. National Archives in Washington, DC, years 1776, 1791, 1849, and 1947; the Danish Rigsarkivet (National Archives) in Copenhagen, Denmark, years 1749-50, 1759, 1787, 1792, 1796, 1805, and 1806; and St. Croix Recorder of Deeds, 1928 to the present, including data on past occupation, cultivation, and location of settlements. John H. Mudie, past consultant with the Fomento Bank in Puerto Rico, provided numerous details on the history of Sion Farm and reviewed the manuscript. The history of research at Estate Thomas by Sheila Ward and colleagues provided a helpful guide for the development of this report. Maya Quiñones of the Geographic Information System and Remote Sensing Laboratory of the International Institute of Tropical Forestry helped develop the maps.

Others who offered assistance or reviewed the manuscript are Patricia Abbott and Wallace D. Williams, Florence Williams Public Library; Brinsley Burbidge, St. George Village Botanical Garden; Roy F. Canton, Virgin Islands Department of Housing, Parks, and Recreation; Heather L. Carty, Virgin Islands Department of Tourism; Paul Chakroff, Raquel Seybert, and Kim E. Thurlow, The Nature Conservancy; William F. Cissel, Zandy Hillis Starr, and Steve Luppert, National Park Service; William C. Coles and Douglas B. McNair, Virgin Islands Department of Planning and Natural Resources; Carol Cramer-Burke and Megan Shoenfelt, St. Croix Environmental Association; Pablo Cruz, Robert L. Hendricks, David Howlett, and Ariel E. Lugo, U.S. Department of Agriculture Forest Service; Olassee Davis, University of the Virgin Islands; David Hayes and Betsy Rezende, St. Croix Landmarks Society and Estate Whim Library; Bent Lawaetz, consultant; Rudy G. O'Reilly, Jr., Natural Resources Conservation Service; Silvie Renaud, Frederiksted Public Library; Elroy Richard, University of the Virgin Islands Library; Joseph Schwagerl, U.S. Fish and Wildlife Service; Iván Vicéns, International Institute of Tropical Forestry; and the entire staff at the Cadastral Office in Christiansted, especially Margaret Acosta. This work was carried out in cooperation with the University of Puerto Rico at Río Piedras.

## Endnotes

Breckon, Gary J.; Kolterman, Duane A. 1993. Final report under Cooperative Agreement No. 14-16-004-92-970 between U.S.Department of the Interior Fish and Wildlife Service and University of Puerto Rico. 19 p. Unpublished report. On file with: U.S. Fish and Wildlife Service, Box 510, Boquerón, PR 00622.

Borie, Louis. 1979. Bugby Hole, St. Croix, U.S. Virgin Islands. 31 p. + 5 appendices. Unpublished report. On file with: Island Resources Foundation, 6292 Estate Nazareth, No. 100, 00802-1104.

García, E.; Garcia, R. 1997. Day and night surveys, May 12-15, 1997. Unpublished tally. On file with; Caribbean National Forest, HC-01, Box 13490, Rio Grande, PR 00745-9625.

Gibney, Eleanor; Ray, Gary; McLean, William. 1991. Endangered plants and animals of the U.S. Virgin Islands. 3 p. Unpublished report. On file with: Department of Planning and Natural Resources, Division of Fish and Wildlife, U.S. Virgin Islands, 42 Estate Mars Hill, Frederiksted, St. Croix, VI 00840.

Kramer, W.P. 1930. Report of forest investigation of Virgin Islands and recommendations. 37 p. Unpublished report. On file with U.S. Department of Agriculture Forest Service, Library, International Institute of Tropical Forestry, Jardín Botánico Sur, 1201 Calle Ceiba, San Juan, PR 00926-1119.

Nature Conservancy. 2003. Forest legacy for the U.S. Virgin Islands: an assessment of need. Unpublished report, prepared for Virgin Islands Department of Agriculture. On file with: The Nature Conservancy, Eastern Caribbean Division, 3052 Estate Little Princess, Christiansted, St. Croix, VI 00820.

Rivera, Luis A. 1997. Analisys [sic] of the management situation. Estate Thomas, Santa Cruz, USVI. 5 p. Unpublished report. On file with: U.S. Department of Agriculture Forest Service, Caribbean National Forest, P.O. Box 490, Palmer, PR 00721.

Rotty, Roland. 1955. Report of Virgin Islands cooperative program in forestry. Report File 7917. Washington, DC: U.S. Department of Agriculture, Foreign Forestry Services, Branch of Foreign Forestry Resources. 8 p. + appendices. Unpublished report. On file with: U.S. Department of Agriculture Forest Service, Library, International Institute of Tropical Forestry, Jardín Botánico Sur, 1201 Calle Ceiba, San Juan, PR 00926-1119.

Tyson, George F. 2005. Historical background: Estate Thomas, No. 24 Queen's Quarter. 4 p. Unpublished report. On file with: Research Library and Archives, #52 Estate Whim, St. Croix, VI 00840.

Valiulis, Jennifer. 2003. A survey of the plants, reptiles and birds of Jack and Isaacs Bay Preserve, St. Croix, U.S. Virgin Islands. 26 p. Unpublished report. On file with: The Nature Conservancy, Eastern Caribbean Division, 3052 Estate Little Princess, Christiansted, St. Croix, U.S. Virgin Islands 00820.

## Literature Cited

**Anonymous.** 1947. The Virgin Islands of the United States. Washington, DC: U.S. Department of the Interior; Governor of the Virgin Islands. 29 p. + pictorial supplement.

**Anonymous.** 1950. Report of a committee of the U.S. Department of Agriculture on agricultural resources, needs, and possibilities of the Virgin Islands. Washington, DC: U.S. Department of Agriculture, Office of the Secretary. 34 p.

**Anonymous.** 1955. Fifteenth annual report. Caribbean Forester. 16: 1-11.

**Anonymous.** 1956. Sixteenth annual report. Caribbean Forester. 17: 1-11.

**Anonymous.** 1957. Seventeenth annual report. Caribbean Forester. 18: 1-11.

**Anonymous.** 1958. The status of forestry and forest research in Puerto Rico and the Virgin Islands: Eighteenth annual report of the Tropical Forest Research Center. Caribbean Forester. 19: 1-24.

**Anonymous.** 1959. 1958 annual report: Tropical Forest Research Center. Caribbean Forester. 20: 1-10.

**Anonymous.** 1960. 1959 annual report: Tropical Forest Research Center. Caribbean Forester. 21: 1-11.

**Anonymous.** 1961. 1960 annual report: Tropical Forest Research Center. Caribbean Forester. 22: 1-11.

**Anonymous.** 1962. Annual report for 1961: Tropical Forest Research Center. Caribbean Forester 23: 1-14.

**Anonymous.** 1963. Annual report for 1962: Tropical Forest Research Center. Caribbean Forester. 24: 1-17.

**Adams, Mary Beth; Loughry, Linda; Plaugher, Linda.** 2004. Experimental forests and ranges of the USDA Forest Service. Gen. Tech. Rep. NE-321. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station: 10-11.

**Ayer, Anthony J.** 1998. Creating green belts and nature preserves. In: Watkins, Priscilla G., ed. Preserving the legacy: the St. Croix Landmarks Society and its role in preserving the personal and architectural heritage of the American Virgin Islands. Frederiksted, St. Croix, U.S. Virgin Islands: St. Croix Landmarks Society: 30.

**Beard, J.S.** 1949. Natural vegetation of the Windward and Leeward Islands. Oxford Forestry Memoirs. 21: 1-132.

**Beatty, Harry A.** 1930. Birds of St. Croix. Journal of the Department of Agriculture of Porto Rico. 14: 134-150.

**Beatty, Harry A.** 1944. The mammals of St. Croix, V.I. Journal of Agriculture of the University of Porto Rico. 28(1): 181-185.

**Bevan, Arthur.** 1940. Possibilities for forestry in the Virgin Islands: St. Thomas, St. John, St. Croix. Caribbean Forester. 2(1): 8-12.

**Boone, R.S.; Chudnoff, M.** 1970. Variations in wood density of the mahoganies of Mexico and Central America. Turrialba. 20(3): 369-371.

**Bowden, Martyn J.; Allen John; Arey, David [and others]** 1968. Water balance of a dry island: the hydroclimatology of St. Croix, Virgin Islands, and potential for agriculture and urban growth. Worcester, MA: Clark University, Graduate School of Geography. 89 p.

**Briscoe, C.B.; Nobles, R.W.** 1962. Height growth of mahogany seedlings. Tropical Forest Note 13. Río Piedras, PR: U.S. Department of Agriculture, Forest Service, Institute of Tropical Forestry. 2 p.

**Briscoe, C.B.; Nobles, R.W.** 1966. Effects of pruning teak. Forest Service Res. Note ITF-11. Río Piedras, PR: Institute of Tropical Forestry. 6 p.

**Britton, N.L.** 1918. The flora of the American Virgin Islands. In: Brooklyn Botanic Garden Memoirs. Brooklyn, NY: 19-118.

**Britton, N.L.; Wilson, P.** 1923-26. Descriptive flora: Spermatophyta. Botany of Porto Rico and the Virgin Islands. In: Scientific survey of Porto Rico and the Virgin Islands. New York: New York Academy of Sciences. Vols. 5, 6.

**Calvesbert, Robert J.** 1970. Climate of Puerto Rico and the U.S. Virgin Islands. Climatography of the United States, No. 60-52. Silver Spring, MD: U.S. Department of Commerce, Environmental Science Services Administration, Environmental Data Service. 29 p.

**Cederstrom, D.J.** 1941. Notes on the physiography of St. Croix, Virgin Islands. American Journal of Science 239(8): 553-576.

**Cederstrom, D.J.** 1950. Geology and ground-water resources of St. Croix Virgin Islands: ground-water resources of a moderately dry island. U.S. Geological Survey Water-Supply Paper 1067. Washington, DC: Government Printing Office. 117 p.

**CH2M Hill Southeast, Inc.** [N.d.]. St. Croix map (Cadastral Office, Christiansted, St. Croix, U.S. Virgin Islands). Gainesville, FL: CH2M Hill Southeast, Inc. 1 p.

**Cissel, William.** 1998. Salt River: a singular site. In: Watkins, Priscilla G., ed. Preserving the legacy: the St. Croix Landmarks Society and its role in preserving the personal and architectural heritage of the American Virgin Islands. Frederiksted, St. Croix, U.S. Virgin Islands: St. Croix Landmarks Society: 42-43.

**Colón-Dieppa, Eloy; Torres-Sierra, Heriberto; Ortiz, Jorge.** 1991. In: U.S. Virgin Islands: floods and droughts: national water summary 1988-89. U.S. Geological Survey Water-Supply Paper 2375. San Juan, PR: U.S. Department of the Interior, Geological Survey: 521-526.

**Comstock, William P.** 1944. Insects of Porto Rico and the Virgin Islands: Lepidoptera (suborder) Rhopalocera (superfamily) Papillionoides (true butterflies) (superfamily) hesperoides (skippers). New York: New York Academy of Sciences. Vol. 12, Part 4: 421-622.

**Copeland, Earl, Jr.** 1976. A handful of emeralds: the U.S. Virgin Islands. Americas 28(2): 19-30.

**Curth, Patrick J.; Frost, Stanley; Gerhard, Lee C.; Multer, H.** 1974. Studies of pre-Holocene Cenozoic carbonate rocks of St. Croix: a progress report. In: Multer, H. Gray; Gerhard, L.C., eds. Guidebook to the geology and ecology of some marine and terrestrial environments, St. Croix, U.S. Virgin Islands. Special Publication 5. Christiansted, St. Croix, U.S. Virgin Islands: West Indies Laboratory, Fairleigh Dickinson University: 155-158.

**Daly, Brian F.** 2004. Native urban forests of the Virgin Islands. In: The future of trees in the Caribbean: Biology, planning and management: Proceedings of the 7th annual Caribbean urban forestry conference and 11th Caribbean foresters meeting. St. Thomas, U.S. Virgin Islands: University of the Virgin Islands Cooperative Extension Service: 1-6.

**Daly, Brian; Zimmermann, T.W.** 2002. Germinating eight tree species native to St. Croix, U.S. Virgin Islands. In: Reflections of the past, visions of the future: Proceedings of the 5th annual Caribbean urban forestry conference. St. Croix, U.S. Virgin Islands: University of the Virgin Islands Cooperative Extension Service: 138-143.

**Daly, Brian F.; Zimmermann, Thomas W.** 2004. Methods for establishing native tree seedlings on degraded sites. In: The future of trees in the Caribbean: Biology, planning and management: Proceedings of the 7th annual Caribbean urban forestry conference and 11th Caribbean foresters meeting St. Thomas, U.S. Virgin Islands: University of the Virgin Islands Cooperative Extension Service: 7-13.

**Damman, Arthur E.; Nellis, David W.** 1992. A natural history atlas to the cays of the U.S. Virgin Islands. Sarasota, FL: Pineapple Press. 169 p.

**Davis, John R.** 2002. Soil survey of the United States Virgin Islands. Washington, DC: Government Printing Office; U.S. Department of Agriculture, Natural Resources Conservation Service; Virgin Islands Department of Planning and Natural Resources; Virgin Islands Cooperative Extension Service; U.S. Department of Interior, National Park Service. 219 p. + maps.

**Dookhan, Isaac.** 1974. A history of the Virgin Islands of the United States. Kingston, Jamaica: Canoe Press, University of the West Indies. 321 p.

**Douglas, Robert.** 1996. Caribbean heritage: architecture of the islands. Trinidad and Tobago: Script-J Printers. 121 p.

**Earsom, S.D.; Hunter, C.; Silander, S., eds.** 2004. Caribbean Islands National Wildlife Refuge complex biological review. Washington, DC: U.S. Fish and Wildlife Service internal document. 147 p.

**Esham, Belinda.** 2004. Urban and community forestry in the U.S. Virgin Islands. In: The future of trees in the Caribbean: biology, planning and management: Proceedings of the 7th annual Caribbean urban forestry conference and 11th Caribbean foresters meeting. St. Thomas, U.S. Virgin Islands: University of the Virgin Islands Cooperative Extension Service: 56-60.

**Ewel, J.J.; Whitmore, J.L.** 1973. The ecological life zones of Puerto Rico and the U.S. Virgin Islands. Res. Pap. ITF-18. Río Piedras, PR: Institute of Tropical Forestry. 71 p.

**Forman, R.T.T.** 1974. An introduction to the ecosystems and plants on St. Croix, U.S. Virgin Islands. In: Multer, H. Gray; Gerhard, L.C., eds. Guidebook to the geology and ecology of some marine and terrestrial environments, St. Croix, U.S. Virgin Islands, Special Publication 5. Christiansted, St. Croix, U.S. Virgin Islands: West Indies Laboratory, Fairleigh Dickinson University: 201-237.

**Fosberg, F.R.** 1974. Sketch of the St. Croix flora. In Multer, H. Gray; Gerhard, L.C., eds. Guidebook to the geology and ecology of some marine and terrestrial environments, St. Croix, U.S. Virgin Islands, Special Publication 5. Christiansted, St. Croix, U.S. Virgin Islands: West Indies Laboratory, Fairleigh Dickinson University: 239-244.

**Francis, John K.** 1995. Mahogany planting and research in Puerto Rico and the U.S. Virgin Islands. In: Lugo, Ariel E.; Lowe, Carol, eds. Tropical forests: management and ecology. New York: Springer: 329-341.

**Francis, John K.** 2000a. *Guaiacum officinale* L. Guayacán, lignumvitae. In: Francis, John K.; Lowe, Carol A. Bioecología de árboles nativos y exóticos de Puerto Rico y las Indias Occidentales. Gen. Tech. Rep. IITF-15. Río Piedras, PR: U.S. Department of Agriculture, Forest Service, International Institute of Tropical Forestry: 243-247.

**Francis, John K.** 2000b. *Swietenia mahagoni* Jacq. Caoba dominicana. In: Francis, John K.; Lowe, Carol A. Bioecología de árboles nativos y exóticos de Puerto Rico y las Indias Occidentales. Gen. Tech. Rep. IITF-15. Río Piedras, PR: U.S. Department of Agriculture, Forest Service, International Institute of Tropical Forestry: 499-505.

**Francis, John K.** 2002. The secondary forest of Estate Thomas, St. Croix. In: Reflections of the past, visions of the future: Proceedings of the 5th annual Caribbean urban forestry conference. St. Croix, U.S. Virgin Islands: University of the Virgin Islands Cooperative Extension Service: 96-104.

**Francis, John K.** 2003a. Growth of small-leaf mahogany crop trees in St. Croix, U.S. Virgin Islands. In: Lugo, Ariel E; Figueroa Colón, Julio C.; Alayón, Mildred, eds. Big-leaf mahogany: genetics, ecology, and management. New York: Springer: 375-378.

**Francis, John K.** 2003b. Mahogany planting and research in Puerto Rico and the U.S. Virgin Islands. In: Lugo, Ariel E; Figueroa Colón, Julio C.; Alayón, Mildred, eds. Big-leaf mahogany: genetics, ecology, and management. New York: Springer: 329-341.

**Francis, John K.; Alemañy, Salvador E.** 2003. Hurricane damage to mahogany crowns associated with seed source. In: Lugo, Ariel E; Figueroa Colón, Julio C.; Alayón, Mildred, eds. Big-leaf mahogany: genetics, ecology, and management. New York: Springer: 94-102.

**Francis, John K.; Gillespie, Andrew J.R.** 1993. Relating gust speed to tree damage in Hurricane Hugo, 1989. Journal of Arboriculture. 19(6): 368-373.

**Geary, T.F.** 1969. Adaptability of Mexican and Central American provenances of *Swietenia* in Puerto Rico and St. Croix. FO-FTB-69-2/19. Breeding for high-yielding characters: Second world consultation on forest tree breeding. Section 2: Rome, Italy: Food and Agriculture Organization of the United Nations, International Union of Forestry Research Organizations: 243-253.

**Geary, T.F.; Barres, H.; Ybarra-Coronado, R.** 1973. Seed source variation in Puerto Rico and Virgin Islands grown mahoganies. Res. Pap. ITF-17. Rio Piedras, PR: U.S. Department of Agriculture, Forest Service, Institute of Tropical Forestry. 24 p.

**Geary, T.F.; Nobles, R.W.** 1980. Selection of some exotic tree species for planting in St. Croix, Virgin Islands. In: Whitmore, J.L., ed. Wood production in the neotropics via plantations: Proceedings IUFRO/MAB/Forest Service Symposium, IUFRO Working Group S1-07-09. Rio Piedras, PR: Institute of Tropical Forestry: 303-307.

**Geary, T.F.; Nobles, R.W.; Briscoe, C.B.** 1972. Hybrid mahogany recommended for planting in the Virgin Islands. Res. Pap. ITF-15. Río Piedras, PR: U.S. Department of Agriculture, Forest Service, Institute of Tropical Forestry. 5 p.

**Gladfelter, E.H.; Gladfelter, W.B.** 1980. Environmental studies of Buck Island Reef National Monument. 3. St. Croix: Fairleigh Dickinson University, West Indies Laboratory. 114 p.

**Gladfelter, E.H.; Gladfelter, W.B.; Hubbard, D.K.; Carpenter, R.C.; Simpson, G.S.** 1979. Environmental studies of Buck Island Reef National Monument, 2. St. Croix: Fairleigh Dickinson University, West Indies Laboratory. 168 p.

**Gladfelter, William B.; Gladfelter, Elizabeth H.** 2004a. Birds of the Southgate Coastal Reserve: the effects of season and pond water levels as controlling factors in community structure. Coast & Harbor SCR Tech. Rep. 5. Woods Hole, MA: Coast & Harbor Institute. 35 p.

**Gladfelter, William B.; Gladfelter, Elizabeth H.** 2004b. Terrestrial habitats of the Southgate Coastal Reserve: dominant plant species and other habitat characteristics. Coast & Harbor SCR Tech. Rep. 6. Woods Hole, MA: Coast & Harbor Institute. 29 p.

**Gladfelter, W.B.; Gladfelter, E.H.; Monahan, R.K.; Ogden, J.C.; Dill, R.F.** 1978. Environmental studies of Buck Island Reef National Monument, 1. St. Croix: Fairleigh Dickinson University, West Indies Laboratory. 144 p.

**Green-Pedersen, S.E.** 1996. The scope and structure of the Danish negro slave trade. In: Tyson, George F., ed. Bondmen and freedmen in the Danish West Indies. St. Thomas, U.S. Virgin Islands: Virgin Islands Humanities Council: 18-53.

**Haagensen, Reimert.** 1995. Description of the island of St. Croix in America in the West Indies. St. Croix, U.S. Virgin Islands: Virgin Islands Humanities Council. 72 p. [translated from the 1758 Danish publication by Arnold R. Highfield].

**Haas, William H., ed.** 1940. The American empire: a study of the outlying territories of the United States. Chicago: University of Chicago Press. 408 p.

**Hatch, Charles E., Jr.** 1972. Virgin Islands National Park: St. John Island ("the quiet place") with special reference to Annaberg Estate, Cinnamon Bay Estate. Washington, DC: Office of Archeology and Historic Preservation. 220 p.

**Hatchette, P.B.** 1858. Statistics regarding landed properties in the island of St. Croix from 1816 to 1857, with a table showing the quantity of sugar shipped from 1835 to 1840 and from 1850 to 1857. Christiansted, St. Croix: St. Croix Avis.

**Holdridge, L.R.** 1967. Life zone ecology, San José, Costa Rica: Tropical Science Center. 206 p.

**Holsoe, Svend E.** 1996. The beginning of the 1848 emancipation rebellion on St. Croix. In: Tyson, George F., ed. Bondmen and freedmen in the Danish West Indies. St. Thomas, U.S. Virgin Islands: Virgin Islands Humanities Council: 160-169.

**Hopkins, Daniel Price.** 1987. The Danish cadastral survey of St. Croix, 1733-1754. Baton Rouge, LA: Louisiana State University and Agricultural and Mechanical College. 330 p. Ph.D. dissertation.

**Howard, Richard A.** 1979. Flora of the Lesser Antilles, Leeward and Windward Islands: Monocotyledonaceae. Jamaica Plain, MA: Arnold Arboretum, Harvard University. Vol. 3.

**Howard, Richard A.** 1988-89. Flora of the Lesser Antilles, Leeward and Windward Islands: Dicotyledonaceae. Jamaica Plain, MA: Arnold Arboretum, Harvard University. Vol. 4, Part 1; Vol. 5, Part 2; Vol. 6, Part 3.

**Hubbard, Dennis K.; Parsons, Karla M.; Bythell, John C.; Walker, N.D.** 1991. The effects of Hurricane Hugo on the reefs and associated environments of St. Croix, U.S. Virgin Islands: a preliminary assessment. Journal of Coastal Research. Special Issue 8: 33-48.

**Hutchins, Harlan; Wakefield, Carol; Cissel, William.** 1990. The mapping of St. Croix 1500-1922. Christiansted, St. Croix: St. Croix Landmarks Society. 8 p.

**Imsand, Shirley; Philibosian, R.** 1987. Exploring St. Croix. Pasadena, CA: Travelers Information Press. 208 p.

**Jensen, Peter Hoxcer.** 1998. From serfdom to fireburn and strike. Christiansted, St. Croix, U.S. Virgin Islands: Antilles Press. 258 p.

**Jones, Kenneth D.** 1995. Native trees for community forests. Christiansted, St. Croix, U.S. Virgin Islands: St. George Village Botanical Garden of St. Croix. 124 p.

**Keogh, Raymond.** 1979. Does teak have a future in tropical America? Unasylva. 31(126): 13-19.

**Kesler, Benjamin R.** 1980. Priceless heritage. Frederiksted, St. Croix, U.S. Virgin Islands: Ben R. Kesler. 55 p.

**Lawaetz, Erik J.** 1991. St. Croix: 500 years pre-Columbus to 1990. Herning, Denmark: Paul Kristensen. 494 p.

**Leck, Charles F.** 1974a. Avifauna of St. Croix. In: Multer, H. Gray; and Gerhard, L.C., eds. Guidebook to the geology and ecology of some marine and terrestrial environments, St. Croix, U.S. Virgin Islands. Special Publication 5. Christiansted, St. Croix, U.S. Virgin Islands: West Indies Laboratory, Fairleigh Dickinson University: 245-255.

**Leck, Charles F.** 1974b. Butterflies of St. Croix. In Multer, H. Gray; Gerhard, L.C., eds. Guidebook to the geology and ecology of some marine and terrestrial environments, St. Croix, U.S. Virgin Islands. Special Publication 5. Christiansted, St. Croix, U.S. Virgin Islands: West Indies Laboratory, Fairleigh Dickinson University: 257-259.

**Lewis, Gordon K.** 1972. The Virgin Islands: a Caribbean Lilliput. Evanston, IL: Northwestern University Press. 382 p.

**Lewisohn, Florence.** 1964. Divers information on the romantic history of St. Croix. Frederiksted, St. Croix: St. Croix Landmarks Society. 71 p.

**Lewisohn, Florence.** 1970. St. Croix under seven flags. Hollywood, FL: Dukane Press. 463 p.

**Liogier, Henri Alain.** 1985-97. Descriptive flora of Puerto Rico and adjacent islands. Spermatophyta. Vol. 1. Casuarinaceae to Connaraceae. Vol. 2. 481 p. Leguminosae to Anacardiaceae. Vol. 3. Cyrillaceae to Mrytaceae. Vol. 4. Melastomataceae to Lentibullariaceae. Vol. 5.. Acanthaceae to Compositae. San Juan, PR: Editorial de la Universidad de Puerto Rico.

**Liogier, Henri Alain; Martorell, Luis F.** 1982. Flora of Puerto Rico and adjacent islands: a systematic synopsis. Río Piedras, PR: Editorial de la Universidad de Puerto Rico. 342 p.

**Little, E.L., Jr.** 1969. Trees of Jost van Dyke (British Virgin Islands). Río Piedras, PR: U.S. Department of Agriculture, Forest Service, Institute of Tropical Forestry. 12 p.

**Little, E.L., Jr.; Wadsworth, Frank H.** 1964. Common trees of Puerto Rico and the Virgin Islands. Agric. Handb. 249. Washington, DC: U.S. Department of Agriculture, Forest Service. 548 p.

**Little, E.L., Jr.; Woodbury, Roy O.** 1980. Rare and endemic trees of Puerto Rico and the Virgin Islands. Conservation Res. Rep. 27. Washington, DC: U.S. Department of Agriculture, Forest Service. 26 p.

**Little, E.L., Jr.; Woodbury, Roy O.; Wadsworth, Frank H.** 1974. Common trees of Puerto Rico and the Virgin Islands. Agric. Handb. 449. Washington, DC: U.S. Department of Agriculture, Forest Service. 1,024 p.

**Lugo-Lopez, M.A.; Rivera, Luis H.** 1980. Updated taxonomic classification of the soils of the U.S. Virgin Islands. Journal of Agriculture of the University of Puerto Rico. 64(2): 131-137.

**MacLean, William P.** 1982. Reptiles and amphibians of the Virgin Islands. London: Macmillan Education. 54 p.

**McGuire, James William.** 1925. Geographic dictionary of the Virgin Islands of the United States. Special Publication 103. Washington, DC: U.S. Department of Commerce, Coast and Geodetic Survey; Government Printing Office. 211 p.

**McKinzie, W.E.; Scott, B.F.; Rivera, L.H.** 1965. Soils and their interpretations for various uses, St. Croix, U.S. Virgin Islands. Spartanburg, SC: U.S. Department of Agriculture, Soil Conservation Service, Cartographic Unit. 67 p.

**McManus, John J.** 1974. Notes on the vertebrates of St. Croix: land mammals, reptiles, and amphibians. In: Multer, H. Gray; Gerhard, L.C., eds. Guidebook to the geology and ecology of some marine and terrestrial environments, St. Croix, U.S. Virgin Islands, Special Publication 5. Christiansted, St. Croix, U.S. Virgin Islands: West Indies Laboratory, Fairleigh Dickinson University.

**McNair, Douglas B.** 2003. Population estimate, habitat associations, and conservation of the St. Croix ground lizard *Ameiva polops* at Protestant Cay, United States Virgin Islands. Caribbean Journal of Science. 39(1): 94-99.

**McNair, Douglas B.; Coles, William.** 2003. Response of the St. Croix ground lizard *Ameiva polops* to severe local disturbance of critical habitat at Protestant Cay: before-and-after comparison. Caribbean Journal of Science. 39(3): 392-398.

**National Climatic Data Center.** 1999. Climatological data annual summary: Puerto Rico and Virgin Islands. Vol. 45, No. 13. Asheville, NC: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service; National Climatic Data Center. 17 p.

**Nellis, David W.** 1997. Poisonous plants and animals of Florida and the Caribbean. Sarasota, FL: Pineapple Press. 315 p.

**Nellis, David W.; Everhard, C.O.R.** 1983. The biology of the mongoose in the Caribbean. In: Hummelinck, P. Wagenaar; Van der Steen, L.J., eds. Studies on the fauna of Curacao and other Caribbean Islands. Utrecht, Netherlands: Foundation for Scientific Research in Surinam and the Netherlands Antilles: 1-163.

**Nobles, R.W.** 1960. Forestry in the U.S. Virgin Islands. Journal of Forestry. 58(7): 524-527.

**Nobles, R.W.; Briscoe, C.B.** 1966a. Height growth of mahogany seedlings, St. Croix, Virgin Islands. Forest Service Res. Note ITF-10. Rio Piedras, PR: U.S. Department of Agriculture, Forest Service, Institute of Tropical Forestry. 3 p.

**Nobles, R.W.; Briscoe, C.B.** 1966b. Killing unwanted West Indian mahogany trees by peeling and frilling. Forest Service Res. Note ITF-8. Rio Piedras, PR: U.S. Department of Agriculture, Forest Service, Institute of Tropical Forestry. 3 p.

**Nobles, R.W.; Briscoe, C.B.** 1966c. Mowing understory vegetation in a young teak plantation, St. Croix, Virgin Islands. Forest Service Res. Note ITF-9. Rio Piedras, PR: U.S. Department of Agriculture, Forest Service, Institute of Tropical Forestry. 2 p.

**Nobles, R.W.; Briscoe, C.B.** 1966d. Root pruning of mahogany nursery stock, St. Croix, Virgin Islands. Forest Service Res. Note ITF-7. Rio Piedras, PR: U.S. Department of Agriculture, Forest Service, Institute of Tropical Forestry. 4 p.

**Oakes,A.J.; Butcher, James O.** 1962. Poisonous and injurious plants of the U.S. Virgin Islands. Misc. Publ. 882. Washington, DC: U.S. Department of Agriculture, Agriculture Research Service. 97 p.

**Oakes, A.J.; Morris, M.P.** 1958. The West Indian weedwoman of the United States Virgin Islands. Bulletin of the History of Medicine. 32(2): 164-170.

**O'Neill, Edward A.** 1972. Rape of the American Virgins. Washington, DC: Praeger. 216 p.

**Philibosian, Richard; Ruibal, Rodolfo.** 1971. Conservation of the lizard *Ameiva polops* in the Virgin Islands. Herpetologica. 27(4):450-454.

**Philibosian, Richard; Yntema, John A.** 1976. Records and status of some reptiles and amphibians in the Virgin Islands, I. 1968-1975. Herpetologica. 32(1): 81-85.

**Prokopetz, A.Wayne.** 1976. Archaeological survey of Buck Island Reef National Monument, St. Croix, U.S. Virgin Islands. Tallahassee, FL: Southeast Archaeological Center. 26 p.

**Rigsarkivet (Danish National Archives).** 1742-1915 (including specific years 1749-50, 1759, 1787, 1792, 1796, 1805, 1806). Copenhagen, Denmark.

**Rivera, L.H.; Frederick, W.D.; Farris, C.; Jensen, E.M.; Davis, L.; Palmer, C.D.; Jackson, L.F.; McKinzie, W.E.** 1970. Soil survey of the Virgin Islands of the United States. Washington, DC: U.S. Department of Agriculture, Soil Conservation Service; U.S. Government Printing Office. 78 p. + maps.

**Rodrigues, Ana S.L.** 2002. U.S. Virgin Islands rapid bird assessment. Christiansted, St. Croix, U.S. Virgin Islands: The Nature Conservancy of the Virgin Islands. 415 p.

**Rogozinski, Jan.** 1999. A brief history of the Caribbean from the Arawak and Carib to the present. New York: Facts on File. 415 p.

**Ryberg, Hugo.** 1945. A list of the names of inhabitants the Dutch Westindian Islands (the Virgin Islands) from 1650-ca. 1825. Copenhagen, Denmark: Royal Danish Stadtarchiv. 337 p.

**Schmidt, K.P.** 1928. Amphibians and land reptiles of Porto Rico, with a list of those reported from the Virgin Islands. Scientific Survey of Porto Rico and the Virgin Islands. 19: 1-160.

**Schuck-Kolben, R. Erik; Kaufman, Lionel.** 1991. Storm-surge flooding by Hurricane Hugo on the U.S. Virgin Islands, Puerto Rico, and South Carolina, September 1989. In: Paulson, R.W., Chase, E.B., Roberts, R.S., Moody, D.W., comps. National water summary 1988-89: Hydrologic event and floods and droughts: U.S. Geological Survey Water-Supply Paper 2375: 59-64.

**Scofield, John.** 1956. Virgin Islands: tropical playland, U.S.A. National Geographic. 109(2): 201-232.

**Seaman, George A.** 1961. Mammals, reptiles, and amphibians of the Virgin Islands. St. Croix, U.S. Virgin Islands. Virgin Islands Fish and Wildlife Service. 10 p.

**Seaman, George A.** 1966. A short history of the deer of St. Croix. Caribbean Journal of Science. 6(1-2): 33-41.

**Seaman, George A.** 1989. A short history of the deer of St. Croix. St. Croix, U.S. Virgin islands: George Seaman. 20 p.

**Seaman, George A.; Randall, J.E.** 1962. The mongoose as a predator in the Virgin Islands. Journal of Mammalogy. 43(4): 544-546.

**Silander, Susan.** 1992. Plantas en peligro de extinción en Puerto Rico e Islas Virgenes. Acta Científica. 6(1-3): 121-126.

**Small, Vonnie.** 1982. Sea turtle nesting at Virgin Islands National Park and Buck Island Reef National Monument, 1980 and 1981. Research/Resources Management Rep. SER-61. Atlanta: U.S. Department of Interior, National Park Service, Southeast Regional Office, Natural Science and Research Division. 54 p.

**Soil Conservation Service.** 1963. Important farmlands. St. Croix: U.S. Department of Agriculture, Soil Conservation Service, Virgin Islands. 1:100,000.

**Somberg, Seymour I.** 1976. Virgin Islands forestry research: a problem analysis. Rep. 9. St. Croix, U.S. Virgin Islands: College of the Virgin Islands; Wilmington, NC; Seymour I. Somberg. 14 p.

**Tanshill, Charles Callan.** 1932. The purchase of the Danish West Indies. Baltimore: Johns Hopkins Press. 548 p.

**Thomas, Toni; O'Reilly, Rudy G., Jr.; Davis, Olasee.** 1997. Traditional medicinal plants of St. Croix, St. Thomas and St. John: a selection of 68 plants. Kingshill, St. Croix, U.S. Virgin Islands: University of the Virgin Islands Cooperative Extension Service. 187 p.

**Tyson, George F.** 1996. On the periphery of the peripheries: the cotton plantations of St. Croix, Danish West Indies, 1735-1815. In: Tyson, George F., ed. Bondmen and freedmen in the Danish West Indies. St. Thomas, U.S. Virgin Islands: Virgin Islands Humanities Council: 83-107.

**Tyson, George; Buckingham, Nancy; Cissel, William.** 2000. St. Croix heritage trail. St. Croix: St. Landmarks Society; Virgin Islands Department of Tourism (foldover brochure).

**Tyson, George F.; Highfield, Arnold R., eds.** 1994. The Kamina folk: slavery and slave life in the Danish West Indies. St. Thomas, U.S. Virgin Islands: Virgin Islands Humanities Council. 246 p.

**U.S. Army Corps of Engineers.** 2004. St. Louis: U.S. Army Corps of Engineers. 1706438_SW20041015 8-bit true color SW quadrant of BEAUREGARD SW..

**U.S. Department of Commerce.** 2003. Population and housing profile: 2000. Washington, DC: U.S. Department of Commerce, Economics and Statistics Administration, Census Bureau. 198 p. + appendices.

**U.S. Virgin Islands Bureau of Economic Research.** 2004. U.S. Virgin Islands annual tourism indicators. Charlotte Amalie, U.S. Virgin Islands: Bureau of Economic Research, Office of the Governor. 4 p.

**Virgin Islands Department of Agriculture, Forestry—Soil and Water Conservation Branch; Virgin Islands Urban Forestry Council.** 2001. Urban forestry in the Virgin Islands: a comprehensive strategic plan for 2001-2005. Kingshill, St. Croix, U.S. Virgin Islands: Virgin Islands Department of Agriculture, Forestry—Soil and Water Conservation Branch; Virgin Islands Urban Forestry Council. 6 p.

**Wadsworth, Frank H.** 1947. The development of *Swietenia mahagoni* Jacq. on St. Croix. Caribbean Forester. 8(2): 161-162.

**Wadsworth, Frank H.** 2002. Birdlife, an associate of trees in residential St. Croix. In: Reflections of the past, visions of the future: Proceedings of the 5th annual Caribbean urban forestry conference. St. Croix, U.S. Virgin Islands: University of the Virgin Islands Cooperative Extension Service: 55-59.

**Ward, Sheila E.; Lugo, Ariel E.** 2003. Twenty mahogany provenances under different conditions in Puerto Rico and the U.S. Virgin Islands. In: Lugo, Ariel E; Figueroa Colón, Julio C.; Alayón, Mildred, eds. Big-leaf mahogany: genetics, ecology, and management. New York: Springer: 29-93.

**Ward, Sheila; Rodriguez, A.; Morgan, R.** 2002. Estate Thomas Experimental Forest: past, present and future. In: Reflections of the past, visions of the future: Proceedings of the 5th annual Caribbean urban forestry conference. St. Croix, U.S. Virgin Islands: University of the Virgin Islands Cooperative Extension Service: 105-114.

**Watkins, Priscilla G.** 1998. Preserving the legacy. In: Watkins, Priscilla G., ed. Preserving the legacy: the St. Croix Landmarks Society and its role in preserving the personal and architectural heritage of the American Virgin Islands. Frederiksted, St. Croix, U.S. Virgin Islands: St. Croix Landmarks Society: 5.

**Wauer, Roland; Wunderle Jr., Joseph M.** 1992. The effect of hurricane Hugo on bird populations on St. Croix, U.S. Virgin Islands. Wilson Bulletin. 104(4): 656-673.

**Weaver, P.L.; Francis, J.K.** 1988. Growth of teak, mahogany and Spanish cedar in St. Croix, U.S. Virgin Islands. Turrialba. 38: 308-317.

**Westergaard, Waldemar.** 1917. The Danish West Indies under company rule (1671-1754) with a supplementary chapter 1755-1917. New York: Macmillan. 359 p.

**Whetten, J.T.** 1966. Geology of St. Croix, U.S. Virgin Islands. In: Hess, H.H., ed. Caribbean geological investigations. Geological Society of America Memoir 98. New York: Geological Society of America: 177-239.

**Whetten, J.T.** 1974. Field guide to the geology of St. Croix, U.S. Virgin Islands. In: Multer, H. Gray; Gerhard, L.C., eds. Guidebook to the geology and ecology of some marine and terrestrial environments, St. Croix, U.S. Virgin Islands. Special Publication 5. Christiansted, St. Croix, U.S. Virgin Islands: West Indies Laboratory, Fairleigh Dickinson University: 129-144.

**Whitmore, Jacob L.** 1971. *Cedrela* provenance trial in Puerto Rico and St. Croix: nursery phase assessment. Turrialba. 21(3): 343-349.

**Whitmore, J.L.** 1978. *Cedrela* provenance trial in Puerto Rico and St. Croix: establishment phase. Res, Note ITF-16. Río Piedras, PR: U.S. Department of Agriculture, Forest Service, Institute of Tropical Forestry. 11 p.

**Whitmore, J.L.; Hinojosa, G.** 1977. Mahogany (*Swietenia*) hybrids. Res. Pap. ITF-23. Río Piedras, PR: U.S. Department of Agriculture, Forest Service, Institute of Tropical Forestry. 8 p.

**Wiley, James W.; Vilella, Francisco J.** 1998. Caribbean Islands. In: Mac, M.J.; Opier, P.A.; Puckett Haecker, C.E.; Doran, P.D., eds. Status and trends of the nation's biological resources. Reston, VA: U.S. Department of Interior, U.S. Geological Survey: 315-349.

**Willocks, Harold W.L.** 1995. The umbilical cord: the history of the United States Virgin Islands from the pre-Columbian era to the present. Christiansted, St. Croix, U.S. Virgin Islands: Harold W.L. Willocks. 525 p.

**Wolcott, George N.** 1953. The food of the mongoose (*Herpestes javanicus auropunctatus* Hodgson) in St. Croix and Puerto Rico. Journal of Agriculture of the University of Puerto Rico. 37(3): 241-247.

**Woodbury, Roy O.; Little, Elbert L., Jr.** 1976. Flora of Buck Island Reef National Monument (U.S. Virgin Islands). Río Piedras, PR: U.S. Department of Agriculture, Forest Service, Institute of Tropical Forestry. 25 p.

**Woodbury, R.O; Weaver, Peter L.** 1987. The vegetation of St. John and Hassel Island, U.S. Virgin Islands. Research/Resources Management Rep. SER-83. U.S. Department of Interior, National Park Service, Southeast Regional Office. 103 p.

**Zube, Ervin H.** 1968. The islands: selected resources of the United States Virgin Islands and their relationship to recreation, tourism and open space. Amherst, MA: University of Massachusetts, Department of Landscape Architecture. 71 p.

# *Appendix A*

Chronology of major events in the U.S. Virgin Islands, mainly St. Croix, with some details regarding Sion Farm and Estate Thomas

| Year | Event |
|---|---|
| **B.C.** | |
| 300-400 | Ciboneys arrive in the Virgin Islands from North, Central, or South America. |
| **A.D.** | |
| 200s | Arawaks from South America settle in the Virgin Islands. |
| 1400s | Caribs raid the Virgin Islands, attacking more sedentary Arawaks. |
| 1493 | Columbus lands at Salt River, names the island Santa Cruz (St. Croix), claims it for Spain. |
| 1505 | Spanish first bring slaves into Caribbean countries. |
| 1555 | Charles V of Spain orders that Native Americans be treated as enemies. |
| 1625 | England and Holland begin small settlements on St. Croix; English remain after Dutch are driven out; Danish West India Company is formed. |
| 1650 | Spanish drive the British from St. Croix; French conquer the British later that year. |
| 1660 | Governor of St. Kitts deeds St. Croix to the Knights of Malta. |
| 1665 | French West Indies Company buys St. Croix from the Knights of Malta. |
| 1672 | Danes colonize St. Thomas. |
| 1674 | French government purchases St. Croix from the French West Indies Company; Danish West India and Guinea Company receives first monopoly on Danish slave trade. |
| 1675 | Danes venture from St. Thomas to nearby St. John but don't settle the island until 1718. |
| 1733 | Danish West India and Guinea Company buys St. Croix from the French government; severe drought in the spring and summer; other dry periods occur in 1789-91, several years in the first half of the 19th century, 1938-42, 1945-48, 1955, 1964, 1967-68, and 1995. |
| 1734 | Danes begin to survey plantations on St. Croix for sugar cane and cotton production. |
| 1749 | Estate Thomas is acquired by William Thomas, who in 1750 sells it to Nicholas Tuite, the owner of the adjacent farm known as Sion Hill. |
| 1754 | Denmark takes all of the Virgin Islands as a crown colony. |
| 1770s | Small-leaf mahogany (*Swietenia mahagoni* Jacq.) is introduced to St. Croix. |
| 1770 | Local newspaper Royal Danish American Gazette begins to publish; in 1844, the newspaper continues as the St. Croix Avis. |
| 1772 | On August 31, a major hurricane destroys 500 buildings on St. Croix; subsequent hurricanes occur in 1785, 1819, 1837, 1867, 1924, 1928, 1956 (Betsy), 1979 (David), 1989 (Hugo), 1995 (Marilyn), 1998 (Georges), and 1999 (Lenny). |
| 1792 | Denmark declares the slave trade unlawful but helps planters buy slaves during a transition period. |
| 1796 | Height of plantation prosperity—54 percent of the island is in sugar cane, with 114 windmills and 144 animal-driven mills. |

*continued*

## *Appendix A (continued)*

Chronology of major events in the U.S. Virgin Islands, mainly St. Croix, with some details regarding Sion Farm and Estate Thomas

| Year | Event |
|---|---|
| 1803 | Denmark abolishes the slave trade. |
| 1816 | First steam mill appears on Estate Hogansborg. |
| 1820s | Sugar beet and cane production elsewhere results in lower sugar prices for St. Croix produce. |
| 1833 | Emancipation of slaves in British colonies by British Parliament impacts Danish West Indies. |
| 1848 | Governor Peter von Scholten frees the slaves in the Danish West Indies. |
| 1867 | United States draws up treaty to purchase St. Thomas and St. John, but the U.S. Senate does not approve it. |
| 1878 | Central Factory (sugar) begins operation near Christiansted. |
| 1879 | Eggers catalogs flora of the Virgin Islands with specimens collected from St. Croix. |
| 1895 | Sugar crisis leads to establishment of Botanical Experiment Station at Estate La Grange. |
| 1898 | During the Spanish-American War, the United States attempts to purchase the Virgin Islands, but Danish reject the proposed treaty. |
| 1907 | Big-leaf mahogany (*S. macrophylla* King) is introduced to St. Croix. |
| 1910 | Agricultural Experiment Station is set up at Anna's Hope to develop resistant sugar cane. |
| 1916 | Cotton cultivation ceases on St. Croix. |
| 1917 | United States purchases the Virgin Islands from Denmark for $25 million. |
| 1918 | U.S. Navy administers the Virgin Islands. |
| 1919 | Eighteenth Amendment prohibits importation and sale of alcohol, with negative impact on Virgin Islands. |
| 1924 | Major flooding on St. Croix; also in 1928, 1956, 1974, 1977, and 1979. |
| 1927 | Virgin Islanders become U.S. citizens; Puerto Ricans begin to migrate to St. Croix. |
| 1928 | Sugar cane cultivation ceases on hillsides of Estate Thomas. |
| | U.S. Department of Agriculture Forest Service conducts research and planting for 2 years; |
| 1930 | Population of St. Croix is lowest in nearly two centuries. |
| 1931 | U.S. Department of the Interior administers the Virgin Islands. |
| 1932 | Virgin Islands Company (VICO) is created as part of Roosevelt's New Deal. |
| 1933 | Twenty-first Amendment repeals prohibition. |
| 1936 | Basic Organic Act replaces old Danish laws and practices with U.S. Constitution. |
| 1940 | Forest Service report cites need for mahogany stand improvement on St. Croix. |
| 1948 | Buck Island Park is created and in 1961 is transferred to the U.S. National Park Service as a national monument; St. Croix Landmarks Society initiates Activities. |
| 1949 | VICO is phased out, and properties are reassigned to the Virgin Islands Corporation (VICORP). |
| 1952 | Small forest nursery is established at the St. Croix Agricultural Experiment Station; several forestry research and management activities and studies are initiated (refer to tables 6 and 7 for details); the Virgin Islands Tourism Board begins to promote the Virgin Islands as a tourist destination; the Christiansted National Historic Site is created. |
| 1953 | VICORP sets aside Estate Thomas for forestry research under the direction of the International Institute of Tropical Forestry (IITF) in Río Piedras, PR. |
| 1954 | Teak (*Tectona grandis* L. f.) introduced to St. Croix. |
| 1955 | VICORP establishes a sawmill and a treatment plant for posts. |

*continued*

## *Appendix A (continued)*

Chronology of major events in the U.S. Virgin Islands, mainly St. Croix, with some details regarding Sion Farm and Estate Thomas

| Year | Event |
|---|---|
| 1956 | All farming ceases on Estate Thomas. |
| 1960 | Fence-post treatment plant (preservatives) is established; a major influx of people to the Virgin Islands begins. |
| 1962 | Harvey Aluminum Corporation is authorized to build a refinery on St. Croix; Alexander Hamilton Airport (later renamed Henry E. Rohlsen International Airport) is completed. |
| 1963 | Forest Service purchases Estate Thomas from VICORP for tropical dry forest research. |
| 1964 | Forest Service chief designates Estate Thomas as an Experimental Forest on March 11. |
| 1965 | Hess Oil is authorized to build a refinery on St. Croix. |
| 1968 | Elective Governor Act passes, allowing for first locally elected governor in 1970. |
| 1973 | St. George Village Botanical Garden begins activities. |
| 1977 | Green Cay Wildlife Refuge (U.S. National Fish and Wildlife Service) is established. |
| 1980 | Population on St. Croix stabilizes through the end of the millennium. |
| 1984 | Sandy Point Wildlife Refuge (U.S. National Fish and Wildlife Service) is established. |
| 1985 | St. Croix Environmental Association is founded. |
| 1990 | The Nature Conservancy begins activities at Little Princess. |
| 1992 | Salt River is added as a U.S. National Park Service unit. |
| 1997 | Secondary forest of Estate Thomas is surveyed by the Forest Service. |
| 2006 | IITF initiates an environmental education program at Estate Thomas. |

# *Appendix B*

Areas serviced by Virgin Islands Housing, Parks, and Recreation on St. Croix

| Name of facility | Area |
|---|---|
| | *(ha)* |
| **Aquatic activity** | |
| Altona Beach Recreation Complex | 6.5 |
| Cane Bay Boat Ramp and Park | 0.4 |
| Christiansted Beach | 4.8 |
| Christiansted Beach Front | 9.3 |
| Cramer's Park | 15.2 |
| Fisher Men Plots (3 sites)[a] | 0.6 |
| Fort Frederik Beach | 0.8 |
| Vincent Mason Coral Resort | 1.8 |
| **Open—secondary vegetation** | |
| Estate La Grange | 7.3 |
| Estate Boetzberg | 7.7 |
| Fairleigh Dickinson (plots 4 and 5) | 69.2 |
| **Passive and mixed recreation** | |
| D. Hamilton Jackson Park | NA |
| Campo Rico Park | 0.1 |
| Williams Delight | 0.4 |
| Marley Park | 0.1 |
| Glynn Recreation Park | 0.8 |
| Limpritch Park | 1.2 |
| Strand Street Park and Bandstand Area | 1.2 |
| La Valley Recreation Park | 0.4 |
| Princess Recreation Park | 0.4 |
| Estate Catherine's Rest | 2.4 |
| Strand Street Mall | NA |
| Peter's Rest Corner | NA |
| Evening Hill | NA |
| Alderville Park | NA |
| Estate Hanna's Rest | 0.8 |
| Estate Mon Bijou | 2 |
| Stoney Ground | 3.2 |
| **Sports** | |
| Isaac Boynes Ball Park | 2.4 |
| Renholdt Jackson Complex | 2 |
| Rudy Krieger Complex | 2.4 |
| D.C. Canegata Ball Park | 5.3 |
| Terrance Martin Softball Park | 1 |
| Paul E. Joseph Stadium | 3.2 |
| Pedro Cruz Ball Park | 2.3 |
| Fort Frederik Recreation Area | 0.8 |
| Horace Clark Complex—Stoney Ground | 3.2 |
| Questa Verde Tennis Courts and Building | 3.6 |
| Total | 162.8 |

NA = area not specified.
[a]Fisher Men Plots: South Slob (0.2 ha), Smuggler's Cove (0.1 ha), and Turner's Hole (0.3ha).

**Weaver, Peter L.** 2006. Estate Thomas Experimental Forest, St. Croix, U.S. Virgin Islands: research history and potential. Gen. Tech. Rep. IITF-30. San Juan, PR: U.S. Department of Agriculture Forest Service, International Institute of Tropical Forestry. 62 p.

Three groups of Native Americans, the Ciboneys, Arawaks, and Caribs, reached the Virgin Islands in pre-Columbian times. Since their discovery by Columbus in 1493, the Virgin Islands have been held or governed by Spain, Britain, the Netherlands, France, the Knights of Malta, Denmark, and the United States. They have also been held or used by groups ranging from estate owners and trading companies to pirates and squatters. European settlement of St. Croix, which began about 1625, resulted in the gradual replacement of that island's native forest with agricultural estates. Estate Thomas, on St. Croix, has had various owners or managers: William Thomas and other individuals from 1749 to 1835, several government entities and two individuals from 1835 to 1963, and the U.S. Department of Agriculture Forest Service since 1963. The island's plantation economy is now history, and St. Croix has become a popular tourist destination. Sugar production and subsistence agriculture were the major land uses through the early 1950s. In 1953, the Institute of Tropical Forestry (now the International Institute of Tropical Forestry), then located in Río Piedras, PR, initiated tropical dry forest research throughout St. Croix, much of it on the 60-ha Estate Thomas. For the first 10 years, field experimentation centered around nursery techniques, seed germination, small-leaf mahogany regeneration and stand improvement, plantation establishment including small-leaf mahogany and teak, weed control, the determination of tree and stand growth rates, sawmilling, wood utilization, and the treatment of fence posts. After 1963, the Institute initiated several formal studies, some long term. These included provenance trials of mahogany (both big-leaf and Pacific Coast mahogany), Spanish cedar, and teak, as well as species adaptability trials. Other studies included hybrid mahogany growth, root pruning of mahogany nursery stock, thinning or frilling of unwanted competition in small-leaf mahogany stands, and plantings of the locally rare lignum-vitae. Although recent hurricanes have severely damaged property on St. Croix, Estate Thomas Experimental Forest survives in the middle of St. Croix, only a short distance from Christiansted, the Agricultural Experiment Station, the university, and the island's high school. The Estate remains a green area on a portion of the island otherwise saturated with houses, shopping plazas, and roads. Plans for the future of the Estate highlight its importance as an urban forest with a history in experimental forestry that links St. Croix with Latin America and Southeast Asia. Unparalleled opportunities exist for forestry education and demonstration, and passive recreation. On an island that treasures its colonial past, the unique history of Estate Thomas should be showcased for all Crucians to appreciate and cherish.

**Keywords:** Estate Thomas, forest research, lignum-vitae, mahogany, Sion Farm, St. Croix.


The Forest Service, United States Department of Agriculture (USDA), is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives—as directed by Congress—to provide increasingly greater service to a growing Nation.