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Mahogany in Belize: A Historical Perspective

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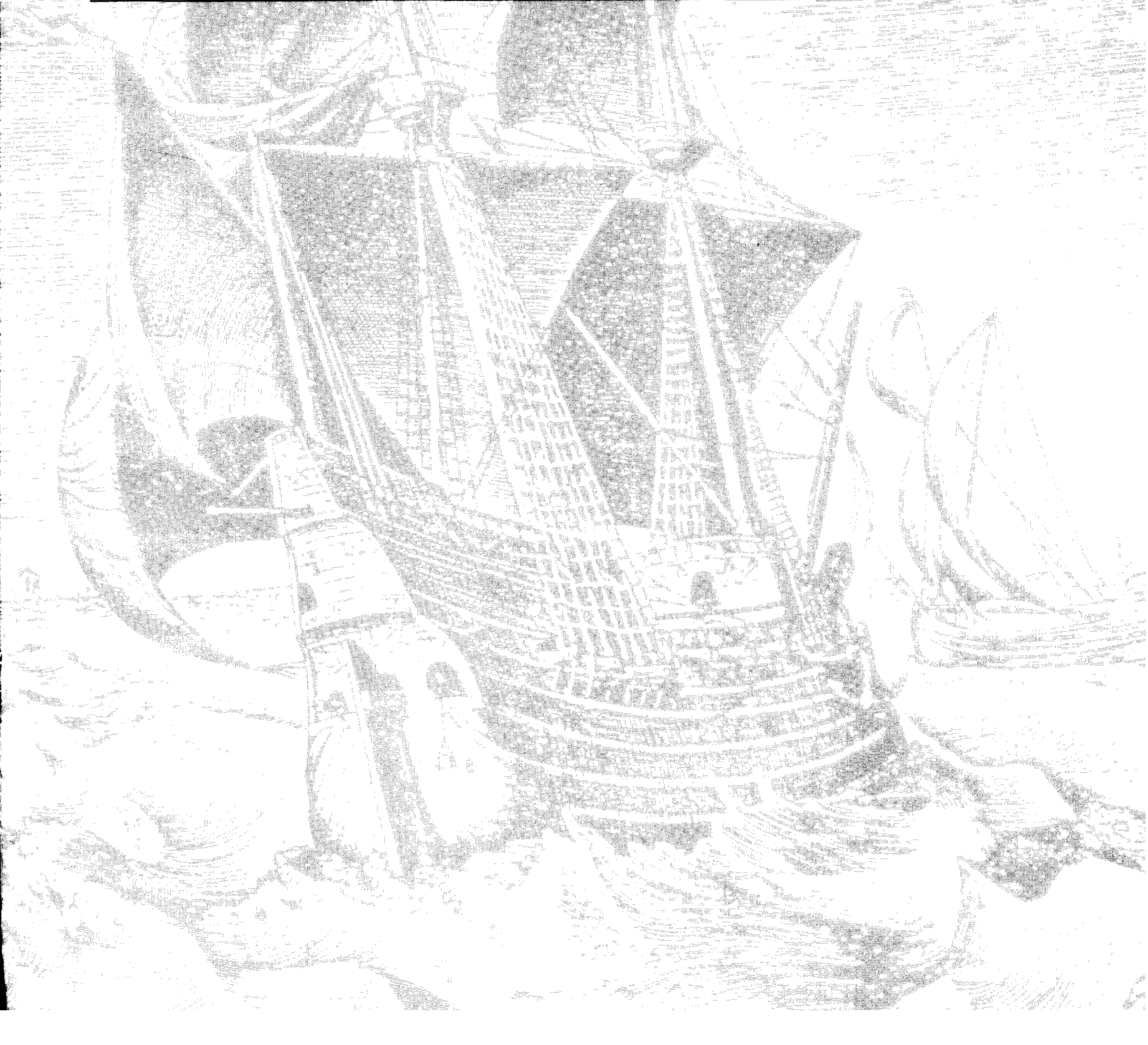

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Abstract

Mahogany (*Swietenia macrophylla* King) in Belize endured the Mayas for 2 millennia; Baymen loggers in the 17th, 18th, and 19th centuries; colonial forest administrations, two World Wars, and a depression in the 20th century; and hurricanes throughout the entire period. Shipwrecked sailors-turned-loggers founded the country, implemented its first forestry rules, and established its dependence on mahogany exports as the main source of income. In the 1920's, the Forest Trust (later the Forest Department) implemented a diversified forestry program. The Department's annual reports provide a rare chronology of activities that include information on mahogany occurrence, silviculture, and research. Belize retains its mahogany resources; however, the country's role as a source of high quality mahogany timber has been seriously eroded by past overcutting. Low population density, a colonial policy that discouraged local agriculture and development, and 20th century attempts at mahogany silviculture and management have lessened the impact on the remaining mahogany resources. Recent national concern about the environment should lead to improved forest policy and management.

Keywords: Belize, conservation, history, hurricanes, mahogany, silviculture.

Introduction

Confined primarily to the Tropics, the Meliaceae is among the most useful plant families because its timbers are commercially valuable and because many of its species can be grown with relative ease in plantations (Pennington and Styles 1975). The subfamily Swieteniodideae includes the genera Cedrela, Toona, Khaya, Entandrophragma, Carapa, and the true mahoganies in the genus *Swietenia* (*S. mahagoni* Jacq., *S. macrophylla* King, and *S. humilis* Zucc.). Big leaf mahogany, *S. macrophylla*, is the premiere producer in the Meliaceae. Mature mahogany, sometimes exceeding 45 meters (m) in height, 25 m to the first branch, and 1.8 m in diameter, is a species of grandeur and majestic proportions (Lamb 1947b, Record 1931). Only teak (*Tectona grandis* L.f.) demonstrates a similar combination of size, availability, and desirable characteristics and approaches mahogany in fame and utility (Lamb 1963).

Mahogany's qualities made it the World's most desired timber and that led to its heavy exploitation throughout its native range (Lamb 1942, Lamb 1966). As accessible supplies diminished, timber substitutes were sought elsewhere. Khaya, a genus with similar wood properties, and with "a legitimate right linguistically, historically and botanically to be called mahogany" (Lamb 1963), was labeled as African mahogany. In time, however, many attempted to take advantage of an expanding market by selling other woods under the name mahogany (Knees and Gardner 1983; Lamb 1963, 1966; Malone 1965; Mell 1917, 1930-32). By 1917, at least 61 species, 24 in the Meliaceae, were listed as mahogany (Mell 1917). A more comprehensive list in the mid-1930's contained almost 200 species in 35 families that were known as some type of mahogany (Melville 1936). Overexploited throughout its natural range, true mahogany's name was purloined by less noble species, or, as so elegantly stated by Gifford (1944), "mahogany is so well and favorably known that many other woods have taken its name in vain."

Neotropical records on mahogany exploitation and management are rare. However, in Belize, a nation founded on timber resources and logging, chief foresters wrote annual reports for more than 60 years. These reports provide historical information on forest administration, policy, management, logging, transportation, protection, finances, legislation, research, education, planning, and mahogany logging and silviculture. This paper consolidates the information from these reports and other documents to render a succinct history of mahogany logging and export activities, silvicultural treatments, and management practices in Belize.

Belize—The Setting

Geology, Physiography, and Soils

Belize encompasses almost 23 000 square kilometers (km^2) of the Caribbean coast primarily between 16° and 18° N. latitude. The northern half of the country (north of the Maya Mountains) is on the Yucatan Platform, which consists of limestone, chalk, marl, and other sedimentary layers. The Maya Mountains, situated in south-central Belize, evolved from a large up-faulted block of intrusive granitic rocks and metamorphosed sedimentary rocks. Rising to about 1120 m, they are the country's oldest geological formation. Additional limestone formations and an area of sedimentary rocks are found south of the mountains. The Coastal Plain, composed of detrital materials derived from western uplands, is about 50 km in width in some areas north of the Belize River and virtually absent at Deep River in the southeast.

Seven principal landforms are recognized in mainland Belize (fig. 1) (Hartshorn and others 1984, Wright and others 1959). These are (1) siliceous soils of the Mountain Pine Ridge; (2) siliceous soils of the Maya Mountains; (3) calcareous soils of karst landscapes; (4) tertiary mudstones, shales, and sandstones of the Toledo Lowlands; (5) calcareous soils of the Northern Lowlands; (6) siliceous soils of the Lowland Pine Ridge; and (7) the littoral complex of organic soils and dune sands. Calcareous soils occupy 51 percent of Belize, siliceous soils 37 percent, and the remaining groups 12 percent.

Climate

Trade winds blow from the east and southeast between February and September; cooler and stronger winds blow from the north and northeast during the winter months (Walker 1973). Rainfall ranges from 1500 millimeters (mm) per year in the north to >4000 mm per year south of Punta Gorda bordering the Caribbean Sea. Relative humidity varies between 80 and 90 percent in the coastal lowlands. A dry season extends from February to May.

The highest and lowest temperatures ever recorded are 42.8 °C in the Sibun Hills in April and 3.3 °C at Punta Gorda in December (Walker 1973). The mean maximum and mean minimum annual temperatures in Belize City, which is typical of the lowlands, are 29.9 and 22.1 °C, respectively. Comparable temperatures for the Maya Mountains at Mountain Pine Ridge are 24.8 and 17.9 °C, respectively. Temperature extremes are greater in the interior than in coastal areas.

Long dry seasons and hurricanes (fig. 2) are the major climatic events that impact Belizean forests. Prolonged dry seasons characterized by low relative humidity provide conditions in which human- and lightening-caused fires can rapidly advance (Wolffsohn 1967). Favorable conditions for fires occur every 5 to 10 years.

Hurricanes, with windspeeds of 120 km per hour or more, have hit Belize causing considerable damage to urban (Cain 1932, 1963) and forested areas (Friesner 1993; Frith 1964; Lamb 1945, 1947a, 1949; Stevenson 1944). The first recorded hurricane was on September 2, 1787 (Gibbs 1883, Lindo 1967). In any 100-year period, meteorologists predict that 33 tropical storms and hurricanes will hit Belize, with hurricanes once every 6 or 7 years (Friesner 1993).

Of the 34 storms listed as hurricanes, 18 had trajectories over Belize and sufficient windspeeds to be classed as hurricanes, 9 could not be verified as hurricanes because they occurred before windspeed data were available (table 1), and the remaining 7 were tropical storms, non-Belizean hurricanes, or nonexistent (Friesner 1993). Belize was hit twice by hurricanes in 1942 and 1961. The longest recorded respite between hurricanes is the current period dating from 1978 to 1997.

Flora

Belize has six ecological life zones: subtropical moist, subtropical lower montane moist, subtropical wet, subtropical lower montane wet, tropical moist, and tropical wet (Hartshorn and others 1984, Holdridge 1967). The 34 vegetation types recognized (table 2) (Wright and others 1959) contain at least 4,000 native flowering plant species (Lundell 1945).

The major vegetation types grow on particular landforms and soils (fig. 1). The siliceous soils of Mountain Pine Ridge and the Lowland Pine Ridge support pine forests and shrub lands. Mangroves and coastal vegetation types grow in the organic soils of the littoral zone. Inland swamps and marshes are concentrated in lowlands along the Hondo, Booths, New River, Belize, and Sarstoon Rivers (fig. 3). The remainder of Belize is covered by broadleaf forests varying in structure and species composition.

History of Mahogany in Belize

Mahogany: Ecology and Occurrence in Belize

Mahogany grows in the neotropics between 20° N. and 18° S. latitude at elevations between 50 and 1400 m (Lamb 1966, Webb and others 1980). Rainfall ranges from 1500 to 4000 mm per year and the mean annual temperature varies between 23° and 28 °C (Webb and others 1980). A dry season lasting up to 4 months is common.

Suitable soils range from deep, poorly drained, acid clays of wooded swamps to well-drained alkaline soils of limestone uplands. Soils may have come from igneous and metamorphic rocks, which are acid to slightly acid in reaction, or alluvial deposits of mixed origin, which are slightly acid to slightly alkaline in reaction (Lamb 1966). Mahogany finds its optimum habitat on deep, well-drained, fertile soils that maintain sufficient moisture during most of the year and that are neutral to slightly alkaline in reaction. These conditions frequently occur in valleys and on gentle, lower slopes. The best growth is attained on medium to heavy textured soils with free drainage (Webb and others 1980).

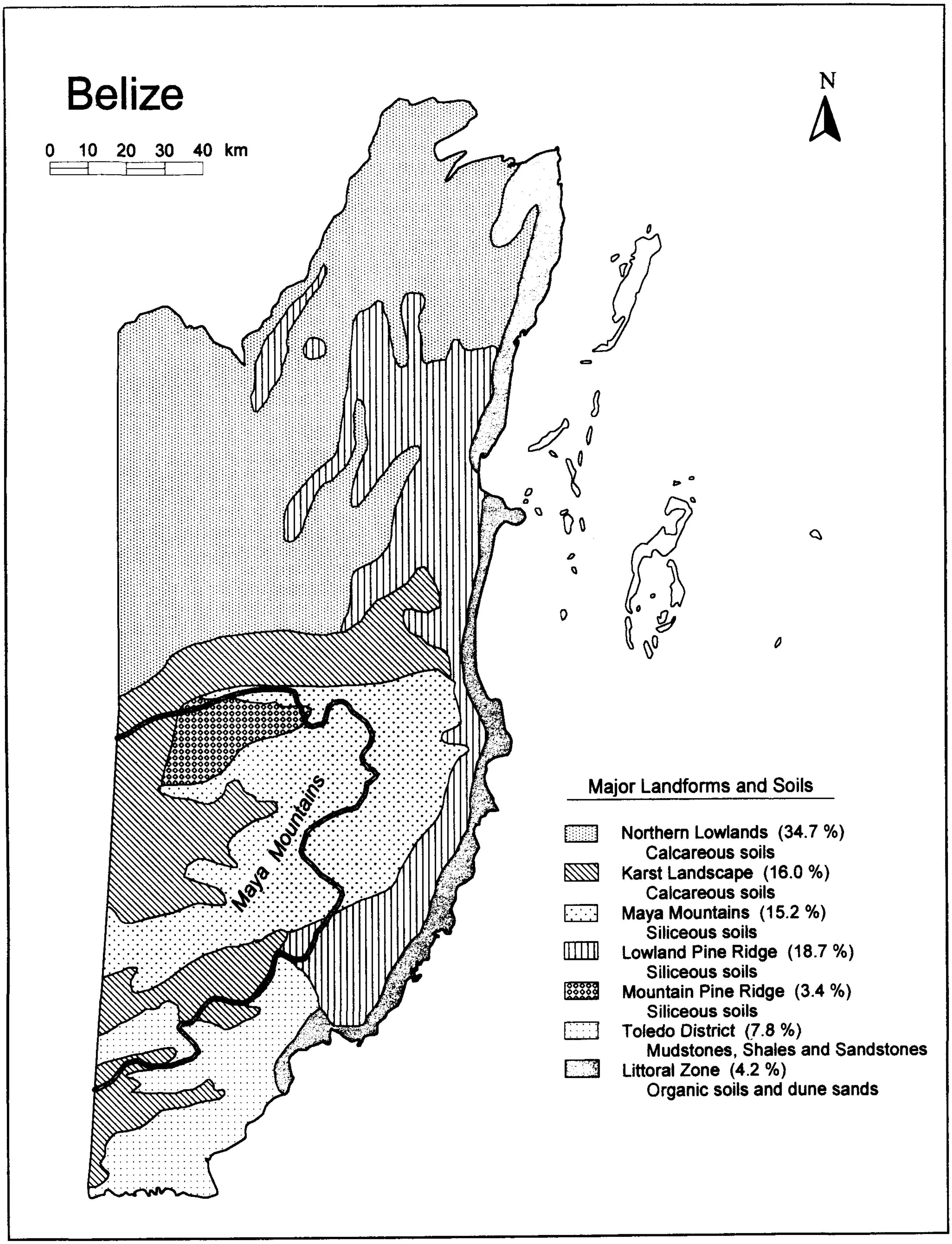

Figure 1—Major landforms and soil features of Belize (Hartshorn and others 1984).

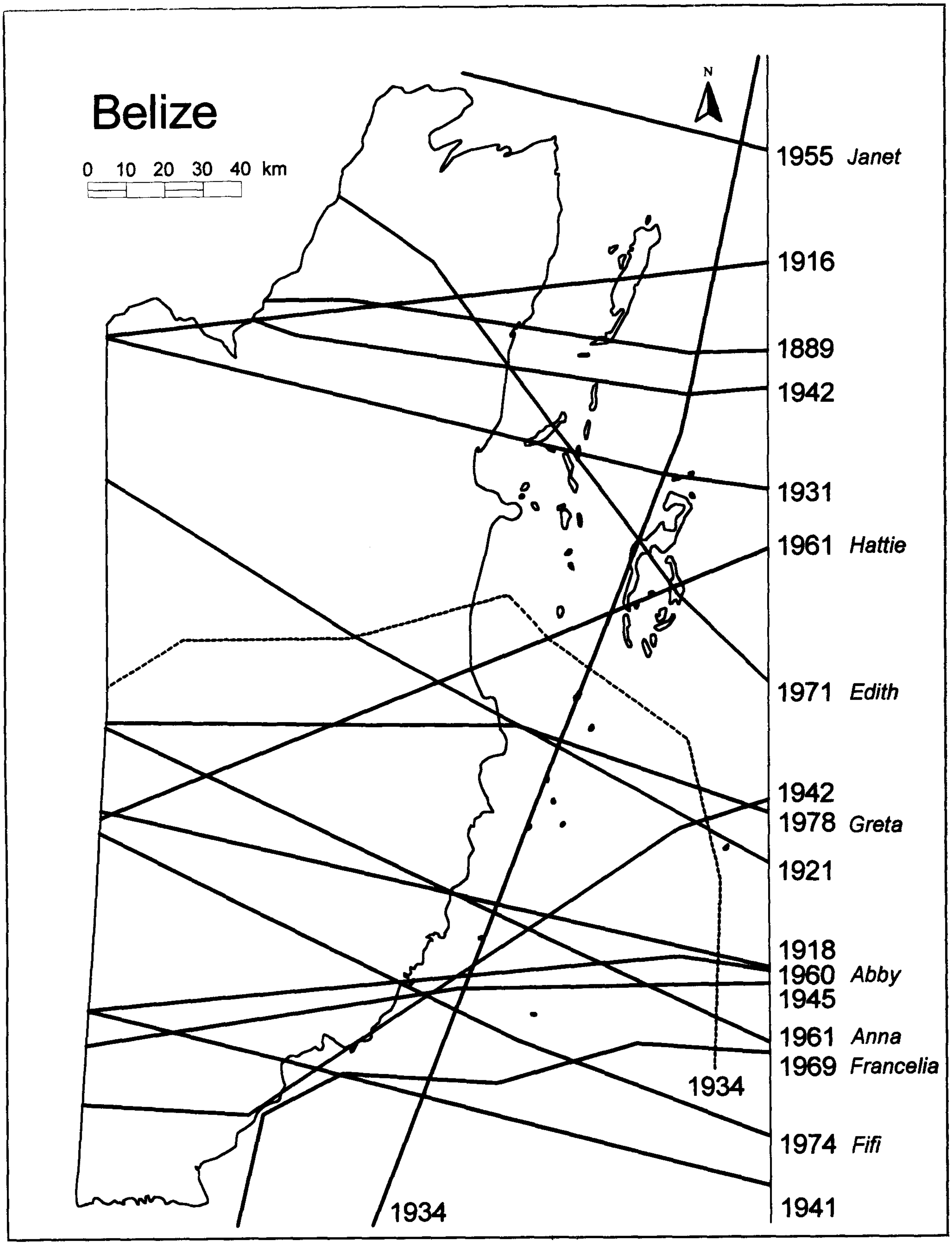

Figure 2—Hurricanes in Belize, 1886 to the present. Hurricanes before 1955 were unnamed. The 1934 event first passed over Belize as a tropical storm and then returned to parallel the coast as a hurricane (Friesner 1993).

Table 1—Summary of reported hurricanes with trajectories over Belize[a] [b]

Year	Month and day						Velocity	Comments
	June	July	Aug.	Sept.	Oct.	Nov.		Name, trajectory, damage
							km/hr	
Possible hurricanes:								
1787	--	--	--	02	--	--	--	Belize City destroyed; sea rose 2.5 m
1805	--	--	--	--	--	--	--	No details
1813	--	--	01	--	--	--	--	Hit Belize City
1813	--	--	13	--	--	--	--	No details
1813	--	--	25	--	--	--	--	No details
1827	--	--	20	--	--	--	--	St. George's Caye flooded
1831	--	--	--	--	--	--	--	Between Belize City and Chetumal, Mexico
1864	--	--	31	--	--	--	--	Hit Belize City; sea rose 1.5 m
1883	--	--	--	--	--	--	--	No details
Hurricanes:								
1889	--	--	--	16	--	--	128–156	Northern part of Belize
1916	--	--	--	01	--	--	128–138	Chetumal area and northern Belize
1918	--	--	25	--	--	--	55–120	Punta Gorda area
1921	--	--	--	--	23	--	190	Near Dangriga
1931	--	--	--	10	--	--	160–210	Sea rose 4.5 m in Belize City; mahogany damage
1934	08	--	--	--	--	--	--	Hurricane winds offshore near Belize City
1941	--	--	--	28	--	--	115	South of Stann Creek; mahogany damage
1942	--	--	27	--	--	--	--	Southern Belize (Toledo); mahogany damage
1942	--	--	--	--	--	08	128	Northern half of Belize
1945	--	--	--	--	03	--	115	Monkey River southward; forest damage
1955	--	--	--	27	--	--	255	Janet, Mexican border; some mahogany damage
1960	--	15	--	--	--	--	115	Abby, between Stann Creek - Monkey River
1961	--	24	--	--	--	--	115	Anna, 80 km south of Belize City
1961	--	--	--	--	31	--	250	Hattie, central Belize; worst hurricane ever
1969	--	--	--	03	--	--	150	Francelia, southern Belize
1971	--	--	--	10	--	--	145	Edith, northern Belize
1974	--	--	--	19	--	--	150	Fifi, southern Belize
1978	--	--	--	18	--	--	150	Greta, 50 km south of Belize City

[a] Source: Friesner 1993. Wind velocities not verifiable before 1889.

[b] An unnamed hurricane in 1893 and Hurricane Carmen in 1974 did not have trajectories directly over Belize but caused some damage within the country; also, tropical storms in 1902, 1920, and 1971 impacted parts of Belize.

Table 2—Major vegetation assemblages of Belize[a]

Vegetation assemblage	Average tree height	Land area
	m	*km²*
Major commercial mahogany forests:		
Broadleaf forests rich in lime-loving species		
Deciduous seasonal forests on limestone (2)	15–30	5 542
Semi-evergreen forests on limestone (2)	24–37	818
Broadleaf forest moderately rich in lime-loving species	30–37	322
Broadleaf forests with occasional lime-loving species		
High evergreen seasonal forest	27–37	354
High semi-evergreen seasonal forest	27–37	547
Broadleaf forests with few or no lime-loving species		
Evergreen seasonal forest	21–30	856
Semi-evergreen seasonal forest	21–30	1 786
Transitional broadleaf forest		
Medium-high deciduous forest rich in lime-loving species	21–27	442
Medium-high semi-evergreen seasonal forest poor in lime-loving species	21–27	1 382
Medium-high evergreen seasonal forest poor in lime-loving species	21–27	493
Total		12 542
Mahogany minor or non-commercial:		
Transitional low broadleaf forests (3)	--	989
Shrub land with pine	--	184
Pine forests and orchard savannas (3)	--	2 415
Marsh and swamp communities (9)	--	2 896
Coastal formations—mangroves and littoral forests (5)	--	1 026
Cohune palm forest	--	1 247
Total		8 757
Other lands	--	1 668
Total (land area of Belize)	--	22 967

[a] Source: Wright and others 1959. The numbers of vegetation types per assemblage are indicated within parentheses. In addition, the authors recognize variants within many of the vegetation types.

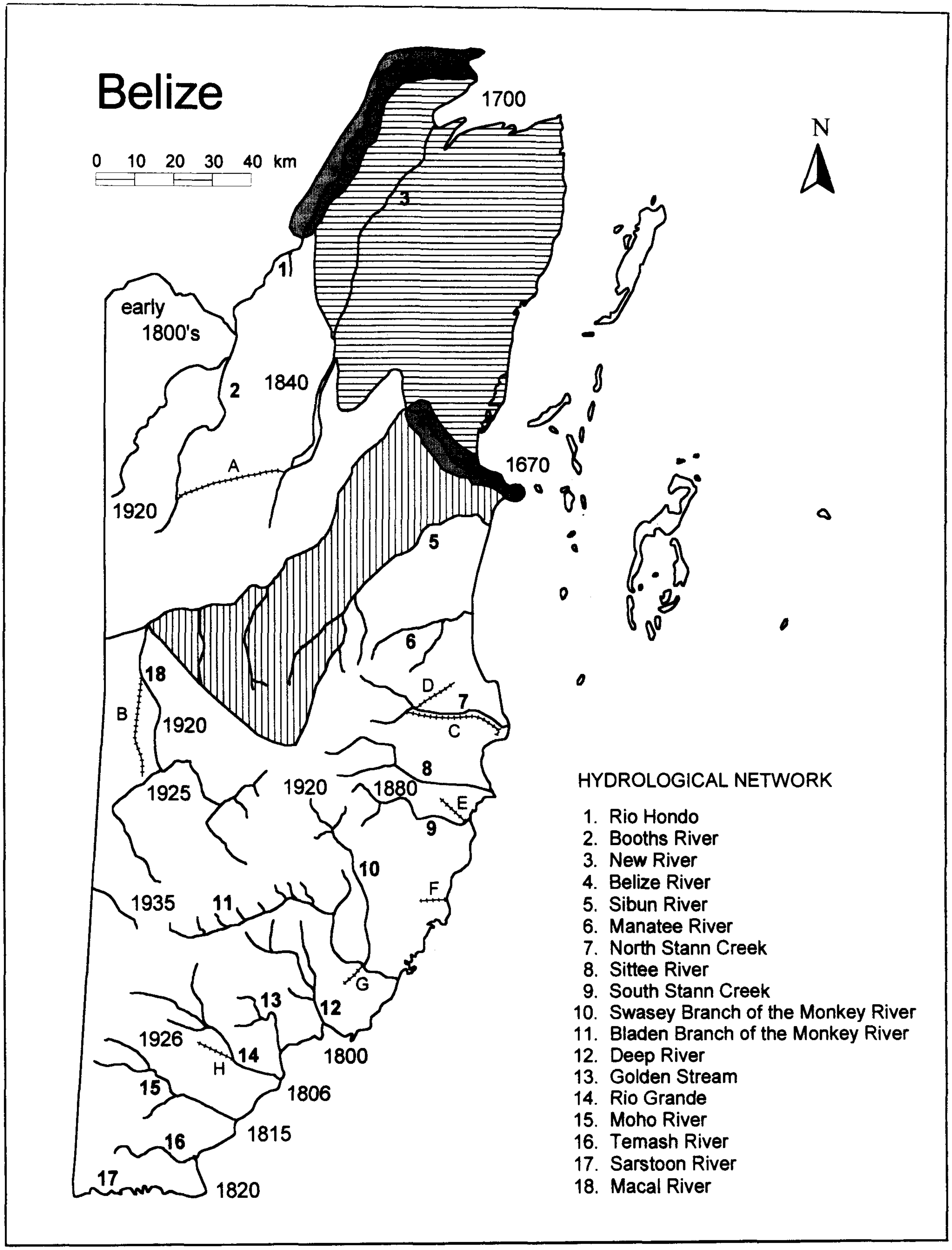

Figure 3—Logging in Belize. The earliest logging areas are shown from 1670 to the early 1700's (shaded areas), lands released for logwood and mahogany harvest by the Treaty of Versailles in 1763 (horizontal lines), and lands released by the Convention of London in 1786 (vertical lines). Dates indicate the advance of loggers throughout Belize in quest of logwood and mahogany. Information on railroads and tramways (indicated by uppercase letters) is presented in table 3 (Bolland 1977; Craig 1969; Dobson 1973; Gibbs 1883; Gregg 1968; Hess 1987; Humphreys 1981; Johnson and Chaffey 1973; Kamstra 1987; Mell 1930-32; Oliphant 1926, 1928b; Waddel 1961).

Under favorable conditions, mahogany flowers and begins to produce seed at 12 years old (Lamb 1966). Although the quantity of seed varies in response to environmental conditions, mahogany may be classed as an abundant seed producer. Mahogany seeds are wind dispersed and do not exhibit dormancy. Germination occurs as soon as the seeds mature. Natural reproduction of mahogany is most abundant where sunlight reaches the soil and where the litter layer is not too deep to prevent the roots of sprouting seeds to reach mineral soil (Lamb 1966). These conditions are often associated with previous disturbance, either natural or human, such as fire (Wolffsohn 1967), clearing, logging, high winds, or hurricanes.

In Belize during the 1920's, mahogany stocking was reported as highest and natural reproduction most profuse in swamp forests where trees were stunted and of little economic importance (Oliphant 1928a). The marl formations in the northern plains were second in mahogany abundance. Earlier, mahogany and cedar were reported as abundant on cohune ridges, which occupy about 40 percent of Belize (Gibbs 1883). Mahogany was not reported in extensive areas along the seacoast where soils are sandy (Markham 1945), in the pine forests of the southern part of the country (Hooper 1887), or in the Mountain Pine Ridge area.

In the early 1930's, mahogany was reported in Belize from sea level to more than 450 m in elevation and from the edges of pine ridges and swamps to climax rain forest (Troup 1932). In the late 1950's, mahogany was specifically mentioned as sparse to abundant in the following forest types, which occupy about 55 percent of Belize (Wright and others 1959): deciduous seasonal forest on limestone, semi-evergreen forest on limestone, broadleaf forest with lime species, and tall transitional broadleaf forest. In the remainder of the forest types, short transitional broadleaf forest, shrub land with pine, pine forest and orchard savanna, marsh communities, coastal formations, and cohune palm forest—mahogany was not specifically noted (Wright and others 1959).

Hurricane Impacts

Hurricane effects on forests were not reported before the 1931 storm that cut an 80-km swath through hardwood forests in a coastal area (Friesner 1993). In 1941, a hurricane hit the Stann Creek District and damage on exposed ridges was notable (Stevenson 1942). Trees were also blown down in patches and swaths at the Silkgrass Reserve. Large mahogany trees survived well and appeared to be wind resistant, but about 15 percent of the poletimber was knocked down on 1135 hectares (ha) that had been under silvicultural treatment for 18 years (Lindo 1967).

In 1942, hurricanes struck in the south during August and in the north in November (fig. 2). The August storm overturned more than 75 percent of the large trees (including mahogany) growing in clay soils; most trees in limestone soils survived (Friesner 1993). In the November storm, more than 75 percent of the canopy species in hardwood forest were destroyed. The remaining mahogany trees were primarily small or medium in size with comparatively thin crowns. Surveys conducted before and after the hurricane indicated that about half of the mahoganies >50 centimeters (cm) in diameter were blown down (Lindo 1967). Projections for mahogany destruction in the 29 630-ha Freshwater Creek Reserve follow: 65,000 trees <30 cm, 95,000 trees ≥30 and ≤60 cm, and 10,000 trees >60 cm in diameter (Lindo 1967). No seed pods were reported in Freshwater Creek in 1943, but some regeneration of mahogany along roads was recorded (Stevenson 1944).

In 1945, a hurricane hit south of Monkey River, cutting a 40-km swath through the forest into Guatemala (Freisner 1993). In 1955, Hurricane Janet hit Belize northeast of the Freshwater Creek Reserve. Damage to the reserve was at least equal to that suffered during the hurricane in 1942. In 1960, Hurricane Abby hit the coast of Belize between Stann Creek and Monkey River, but forest damage was minimal.

Hurricane Hattie, the severest storm in memory, approached Belize from the northeast and moved in a gentle arc into the Maya Mountains on October 31, 1961 (Friesner 1993; Frith 1962, 1964; Lindo 1967). Winds were estimated at >250 km per hour with gale force winds extending 320 km to the north and 220 km to the south. Damage was most severe in the Grant's Works, Commerce Bight, Mango Creek, Swasey Bladen, and Deep River Forest Reserves.

Posthurricane damage estimates in the hardwood forests focused on tree species and distance from the storm trajectory. The greatest damage occurred in the inner zone, ≤25 km north and ≤15 km south of the trajectory, where only 20 percent of the trees survived with more than one-half of their crowns. In the middle zone, >25 to ≤50 km north and >15 to <30 km south, about 50 percent of the trees survived with more than one-half of their crowns. Damage was generally minor in the third zone, >50 km north and >30 km south. However, small pockets of damage occasionally approached that of the second zone. Thirteen hardwood species studied were assigned classes based on the amount of damage suffered, ranging from most severe (class 1) to slight damage (class 3). Mahogany suffering moderate damage was ranked in class 2 defined as standing trees with complete defoliation but <50 percent crown damage. In multiple species plantations, pole-size mahoganies survived better than secondary species (Lindo 1967). Large trees were less windfirm and more liable to break than small trees. Little descriptive information about hurricane damage to forests is available in Belize after Hurricane Hattie.

Human Occupation

The oldest Maya remains at Cuello, Belize, date back to 2500 B.C. (Krohn 1987 and Appendix A). The early to middle pre-classic period (2000 to 300 B.C.) was characterized by village life in scattered communities. The Mayan culture prospered, reaching an estimated population of 400,000 to 1 million in Belize alone (Hartshorn and others 1984), then declined about A.D. 900.

Past evidence of Mayan occupation is visible in vegetation patterns throughout the region (Bartlett 1935, Budowski 1959, Lundell 1937, Wright and others 1959). When Mayas cleared the land to cultivate subsistence crops, they spared useful tree species that provided fruit [ramona (*Brosimum alicastrum*), avocado (*Persea americana*), and mamey apple (*Calocarpum mammosum*)], resin (*Achras zapota* and *Bursera simaruba*), oil (*Orbignya cohune*), and useful wood [*Cedrela mexicana* (hereafter, cedar) and *S. macrophylla*]. It also appears that Mayas may have planted mahogany in belts for shade and timber (Gregg 1968).

During the 600 years between the Mayan decline and the discovery of the New World, Belize was sparsely inhabited. In 1502, Columbus explored the Bay of Honduras in quest of a passage to the Pacific Ocean (Gibbs 1883). In 1524, Cortez apparently passed through southern Belize during an overland march from Mexico City to Honduras (Wright and others 1959 and Appendix A). After Cortez's expedition, the Spaniards maintained a presence in Central America and the Caribbean islands but showed little interest in Belize. The English already occupied Belize by the time Spain conquered the Peten region of Guatemala in 1698 (Buhler 1976, Krohn 1987). Belize exists because Spain never effectively occupied the region.

The Belize coast was settled by shipwrecked British subjects in 1638 (Lindo 1967). The demand for dyes derived from logwood (*Haematoxylum campechianum*) and later for mahogany timber (Benya 1979a, Hooper 1887, Lamb 1947c) provided gainful employment for the British settlers (Baymen) of Belize (Wright and others 1959). During the 1700's, Spaniards attacked the settlements incessantly and the colony was nearly abandoned (Hooper 1887). However, Spain was not interested in colonizing, only preventing a rival power from exploiting the resources (Furley 1968). In 1763, the Treaty of Paris ended the war between Spain and England and allowed the Baymen to cut and export logwood from Belize but retained Spanish sovereignty over the territory (fig. 3 and Appendix A). In 1786, Spain and England signed the Convention of London, which forbade the establishment of sugar and coffee plantations and any settlements but allowed timber harvest, "not excepting even mahogany" (Standley and Record 1936). In 1805, the settlers considered themselves a colony not subject to foreign domination and declared that no Spaniard could cut wood in Belize (Hooper 1887).

In 1825, the population in and around Belize City was estimated at 5,178 persons (Wright and others 1959). No estimates are available for the interior. With the collapse of Spanish colonial rule in Central America, Belize became a safe and desirable place to live and by 1848, the population had increased to 25,000. In 1861, the settlements formally became a colony (Hooper 1887).

From 1638 to 1900, the existence of Belize depended on the export of forest products (Hooper 1887). Like many other territories, its economy was based on a single resource—in this case, timber (Ashcroft 1972). Because forestry operations never required a large number of laborers nor major infrastructure, the lack of permanent settlement and investment, both discouraged by the uncertain nature of Belize's political status (Wright and others 1959), did not negatively impact logging. Rivers served as the principal transportation routes, and local agriculture was confined to subsistence crops (Ashcroft 1972). During this period, Belize City emerged as a trading port for the Central American region with its population dependent on imported goods. The country's population continued to grow slowly from 45,291 in 1921 (Hummel 1925) to 51,347, or about 15 persons per km^2, by 1931 (Troup 1940). When forestry declined during the depression, workers shifted to agriculture. Export agriculture continued to expand, finally exceeding forest products in value during the late 1950's (Overseas Development Administration 1989).

Belize's population in 1980 was 145,350 (Hartshorn and others 1984), increasing to 176,000, or 50 persons per km^2, by 1989 (Overseas Development Administration 1989).

About one-half the population lives in the seven largest towns, the remainder in small communities. The country is multilingual, reflecting a variety of ethnic backgrounds. About one-half the population speak English or its Creole variant; about one-third speak Spanish; and the remaining one-sixth speak Garifuna (Black Carib), Maya, German, or other languages.

Early Logging Activities

Logwood, the source of a dye used by early European textile industries, was the first important forest product from Belize (Hooper 1887, Troup 1940, and Appendix A) and exports to England started about 1655. The mahogany trade began about a century later and by 1771, it had supplanted logwood as the country's chief product. In 1774, Belize's largest recorded mahogany, measuring 3.65 m in diameter, was felled (Peet 1954).

Among mahogany's principal uses in the 18th and 19th centuries, were boat building and furniture making (Nickerson 1963). The sudden rise in the character of English cabinetmaking, including highly ornate chimney pieces and sideboards, was attributed to the arrival of mahogany (Robinson 1881). Craftsmen treasured the wood for its variations in color and figure, dimensional stability, and strength. In addition, they valued the ease with which they could work the wood with either hand or machine tools (Palmer 1978, Record 1931, Saks 1953).

The earliest Belizean laws, adopted around 1665 for logwood extraction in unsurveyed areas, were agreements made by loggers (Hooper 1887, Wright and others 1959). Logwood grows in the swamp forests of northern and northwestern Belize, and the Belize and New Rivers were the principal harvest areas (Furley 1968). When a logger found a logwood site along a river, he would build a hut. On the river shoreline, his property encompassed the area 1,000 paces on either side of the hut. The property also extended from the river to the water divide. Other loggers respected his claim. By 1684, similar agreements existed for harvesting mahogany (Hooper 1887).

These agreements were later replaced by a system of land grants allocated by the superintendent of the settlement. Unsurveyed logwood and mahogany felling areas known as works were determined in a two-step process. First, a starting point on a river or creek was selected, usually at a confluence or some other recognizable feature. Second, the base line of the work extended 3 miles (4.8 km) along the river and the lateral boundaries half way to the next navigable river. The usual distance for lateral boundaries was 8 miles (12.8 km), and a navigable stream would float a mahogany log in the wet season.

After the settlers exploited the mahogany works, they sold them to wealthy individuals. These individuals gradually consolidated the works into estates, chiefly in the northern part of the country (Hooper 1887). Harvesting for 200 years decreased the abundance of mahogany in Belize, but unlike clearing land for farming, it did not devastate the forest. By the late 1930's, almost one-half of the country was privately owned, including the best and most accessible mahogany stands (Troup 1940). The crown lands—forested areas remaining in State ownership (fig. 4)—had been unattractive to early land grant applicants because logwood or mahogany was absent or inaccessible (Gill 1931, Troup 1940).

Inventory and Harvest Techniques

Mahogany was first logged in northern Belize where harvesting was limited to rivers and streams (Harrison 1949) (fig. 3). The distances from felling sites to rivers were increased around 1700 when slaves were introduced from Jamaica to haul logs and again after 1800 when oxen were imported (Appendix A). In the early 1800's, logging advanced south along the rivers (fig. 3) but not inland. The advent of railroads (Wright 1977) and tractors opened additional areas in the early 20th century. However, major logging operations were delayed in the south and southwest until all-purpose roads and heavy logging equipment appeared after World War II (Furley 1968).

The earliest inventories were conducted by experienced "hunters" who roamed the land grants during the dry season looking for yellowing mahogany leaves in the tree tops (Hooper 1887). They noted mahogany locations and extraction routes and estimated the merchantable supply of timber. This information was used to plan the next season's work. Later, mahogany was cruised using a mile square (1.6 km square) grid with north-south lines lettered and east-west lines numbered for subsequent location of timber (Miller 1941). Road clearing through each land grant and to each mahogany tree comprised the greatest expense of the logging operation. Locating mahogany in Mexico from small aircraft began in 1925 and later spread to other areas (Lamb 1966).

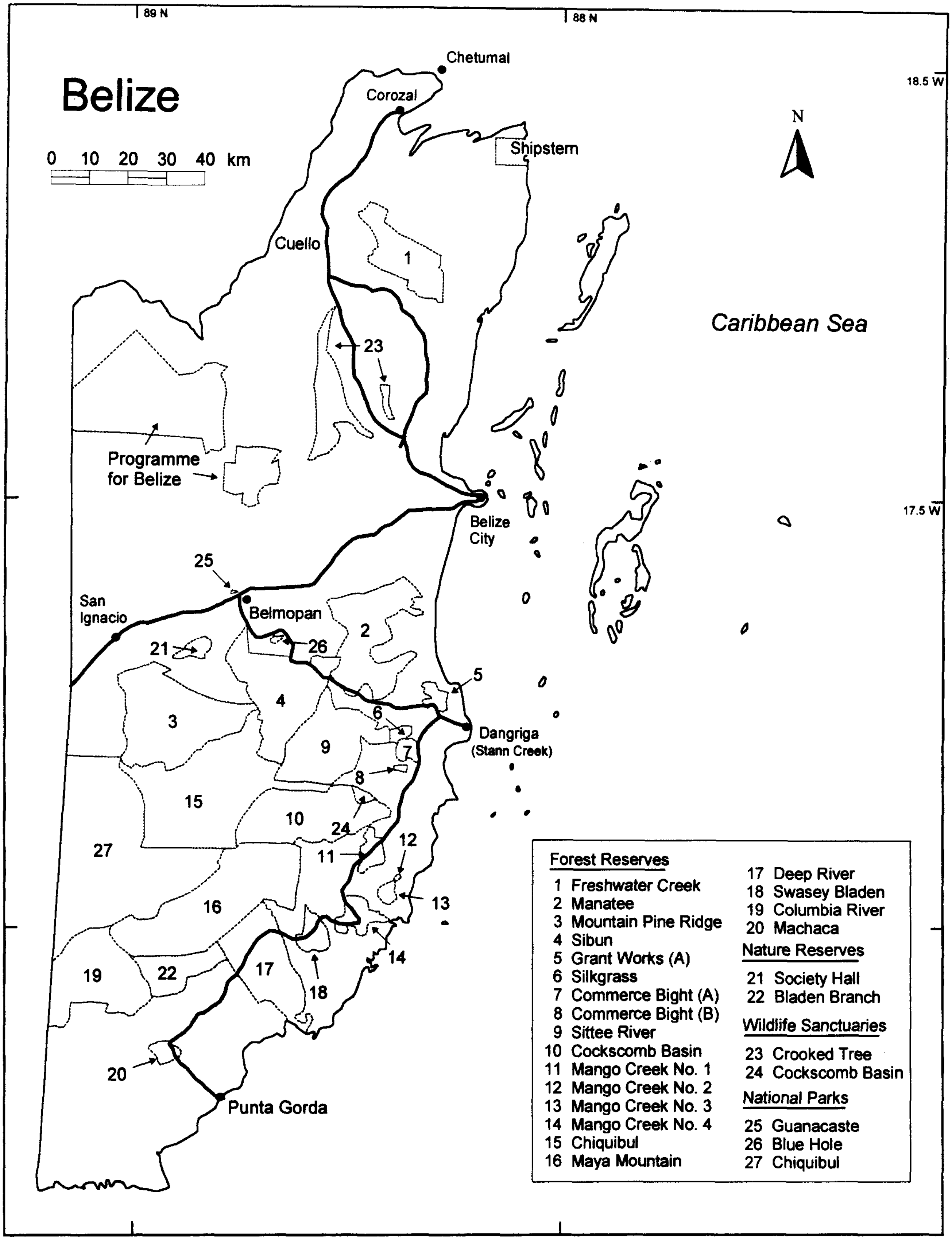

Figure 4—Forest reserves, nature reserves, wildlife sanctuaries, and national parks in Belize.

Logging operations in Belize were complicated by isolation, weather, labor difficulties, and transportation problems (Lamb 1948b). Logging was carried out during the short, dry season along rivers and several kilometers inland (Lamb 1947a, Miller 1941). The loggers traditionally cut the trees above the buttresses. This practice required scaffolding and often resulted in losses of 3 m or more of the best timber. Logs were bucked by two men using 8-foot saws. Loaded on wagons, logs were dragged by oxen, often at night by torchlight, to a wharf where they were squared to remove sapwood in preparation for shipping (Hooper 1887, Hummel 1925, Mell 1917). Some hauls from harvest site to river covered 65 km (Markham 1945). In the 1920's, logs were skidded by eight-wheeled wagons. As many as four or five wagons in tandem, each holding two or three logs, were drawn by crawler tractors (Furley 1968, Harrison 1949, Lamb 1966, Markham 1945, Miller 1941). With the advent of railroads, logs from isolated areas could be shipped inexpensively over land (Benya 1979b). At one time, Belize had about 140 km of railroads in different parts of the country (table 3). However, as mahogany was logged from the areas served by the railroads, they declined in importance. Because good roads were not yet available, logs once again were floated to the coast.

Logs were stored along the shoreline until the rivers were high enough to float them (Lamb 1948b). They were then fastened by chain into rafts, sometimes 150 m or more in length, and floated to the coast (Benya 1979b). Floating was dependent on stream size and weather. In dry years, floating was impossible and the logger either left logs in the forest or gambled that the water flow was sufficient to carry them downstream. In flood years, logs were often scattered on shore, crushed by rocks, or lost in swamps (Markham 1945). When river levels were satisfactory, logs were floated to the coast where they were loaded on steamships or floated by sea to coastal mills. These inefficient logging practices resulted in the loss or damage of much timber.

Shortly before World War II, better roads were constructed into the interior and logs were moved by truck (Harrison 1949). Until then, numerous large, well-distributed mahoganies grew within previously exploited forests (Howell 1994). Some survived because they had butt rot and others survived because their large size exceeded the capacity of the extraction equipment. Previous loggers left them in the forest where they incidentally served as seed trees (Howell 1994). After World War II, the arrival of heavy road building equipment, the construction of all-weather roads, and the use of large logging trucks shifted emphasis away from water transport and opened previously inaccessible areas. The large mahoganies were harvested, sawn locally, and exported. By the 1970's, "over-mature" mahoganies in Belize were a memory.

Table 3—Railroads and tramways in Belize used to carry timber and other products[a] [b]

Endpoint(s) (forest area)	Dates	Length	Map location[c]
		km	
Gallon Jug-Hillbank Belize Estate & Produce	1926–65	42	A
Vaca Falls Mountain Pine Ridge	1914–25	16	B
Middlesex-Commerce Bight Melinda	1905–38	40	C
Mullins River-Middlesex Manatee	1928–30	14	D
Regalia-All Pines Commerce Bight	Early 1900's	11	E
Riversdale National lands	Early 1900's	3	F
Sennis River-Swasey Branch Private lands	Early 1900's	5	G
Machaca River-Jacinto Landing National lands	Early 1900's	10	H

[a] Middlesex-Commerce Bight for bananas and some timber.
[b] Sources: Anon. 1989; Stevenson 1929; Wright 1977; and Map Section, Archives Department, Belmopan.
[c] Approximate locations of railroads and tramways are shown in figure 3.

Chronology of Mahogany Exports

Any attempt to accurately estimate the volume of mahogany harvested in Belizean forests since the early 1700's is confounded by numerous factors:

- Different units and conversions (Lamb 1966) and different scaling techniques used by exporters and importers (Hooper 1887).

- Volumes lost at the stump by cutting above the buttresses, possibly from 200 to 500 board feet (0.5–1.2 m^3) for larger trees (Mell 1917), and volumes lost by squaring logs before shipment (Hooper 1887).
- Logs stranded in the field, rivers, or ocean due to drought, flooding, or storms and timber used within Belize.
- Incomplete or inaccurate records (Howell 1994).
- Reexports of mahogany cut in Mexico and Guatemala (Furley 1968, Lamb 1966).

Despite these limitations, reported mahogany exports provide an appreciation for its importance in trade during the last two centuries (fig. 5) with the following caveat, "all data, all statistics, in Belize should be treated with the utmost caution" (Howell 1994). Most export data were never precise but the inaccuracies have increased in recent years because shipments to Mexico were deliberately underestimated to avoid Mexican import taxes (Howell 1994).

It is unlikely that much mahogany was cut in Belize before 1725 and reliable records are unavailable before 1802 (Standley and Record 1936). Experienced loggers estimated that only one-half of harvested mahogany logs were loaded on ships (Lamb 1966). A very conservative estimate of mahogany cut in Belize since 1800 (based on figure 5, averaged for missing years, and doubled to account for lost timber or recent underreporting) is about 1.5 billion board feet (using standard conversions, 127 million cubic feet, or 3.6 million cubic meters). Assuming that one-half of Belize's land area contained some mahogany (table 2), total production would have averaged about 3 m^3 per ha.

Although mahogany was the chief export for more than 200 years, it supported an unstable economy in Belize because the price fluctuated with demand in England (Bolland 1977). The "boom and bust" pattern resulted from completely different sets of factors: (1) external, fluctuations in World market demand based on overcutting and overstocking of the annual cut; and (2) internal, local weather conditions impacting the harvest and movement of logs to the coast (Furley 1968). Production wavered between 2 and 6 million board feet during much of the 19^{th} century; these figures represent the maximum amounts that could be cut under existing circumstances (Gregg 1968) (fig. 5). The high export years, peaking in the 1840's, responded to demand for railroad carriages in Europe (Furley 1968). All accessible trees were cut, and available timber resources were depleted (Bolland 1977). Moreover, when Belizean loggers moved inland where production costs were greater, profits declined. In the 1850's, the decline in mahogany trade was associated with the substitution of iron for wood in the construction of ships. The depression in sales in the late 1860's was related to Indian attacks in the interior (Bolland 1977).

American firms entered the market soon after 1900 and prompted a short-lived boom for Belize through 1914 (Tucker 1992). Other notable fluctuations were associated with a high demand before World War I, a decline in demand during the war years, and reckless cutting in the mid-1920's. The voluminous exports in 1927 (Tucker 1992) were followed by a precipitous drop associated with the depression in 1930, and a recovery in the mid-1930's. After World War II, the trade connection with the United States weakened. Mahogany exports fluctuated through the late 1950's when they began to decline, reaching their lowest levels in the mid-1980's. The recent increase in exports approaches levels attained in the mid-1960's.

Mahogany Today

Reports on mahogany density and/or volume based on inventories or field observations in Belize are highly variable (table 4). In 1921, stands with 1.2 to 2.5 exploitable trees per hectare, including those of the Belize Estate & Produce Company (BEC) in northwestern Belize, were considered good for timber harvest (Hummel 1925, Miller 1941). Subsequently, the mahogany on the BEC lands declined to an average of 0.5 per ha in 1960 and 0.25 per ha in 1972–83 (Munro 1989). Today, available mahogany has virtually disappeared, particularly in accessible mixed, high forest on privately owned lands, because of past logging practices.

From the earliest days of mahogany harvest through the middle of the 20^{th} century, forest management in Belize was primarily mahogany management (Howell 1994). Traditionally, mahogany logging was the heavy felling of the best trees. Trees too large to cut remained in the forest, incidentally serving as seed sources. A 30- to 40-year period of inactivity followed before the next cutting cycle (Howell 1994). This approach fortuitously resulted in a simple but effective management system. In the past two to three decades, however, the exploitation of mahogany has been intensive.

Mahogany was originally exported as roundwood. In 1933, the BEC installed the country's first sawmill in Belize City (Stevenson 1933), after which domestic sawmilling was required. By 1957, there were 30 sawmills (Cree 1957); by

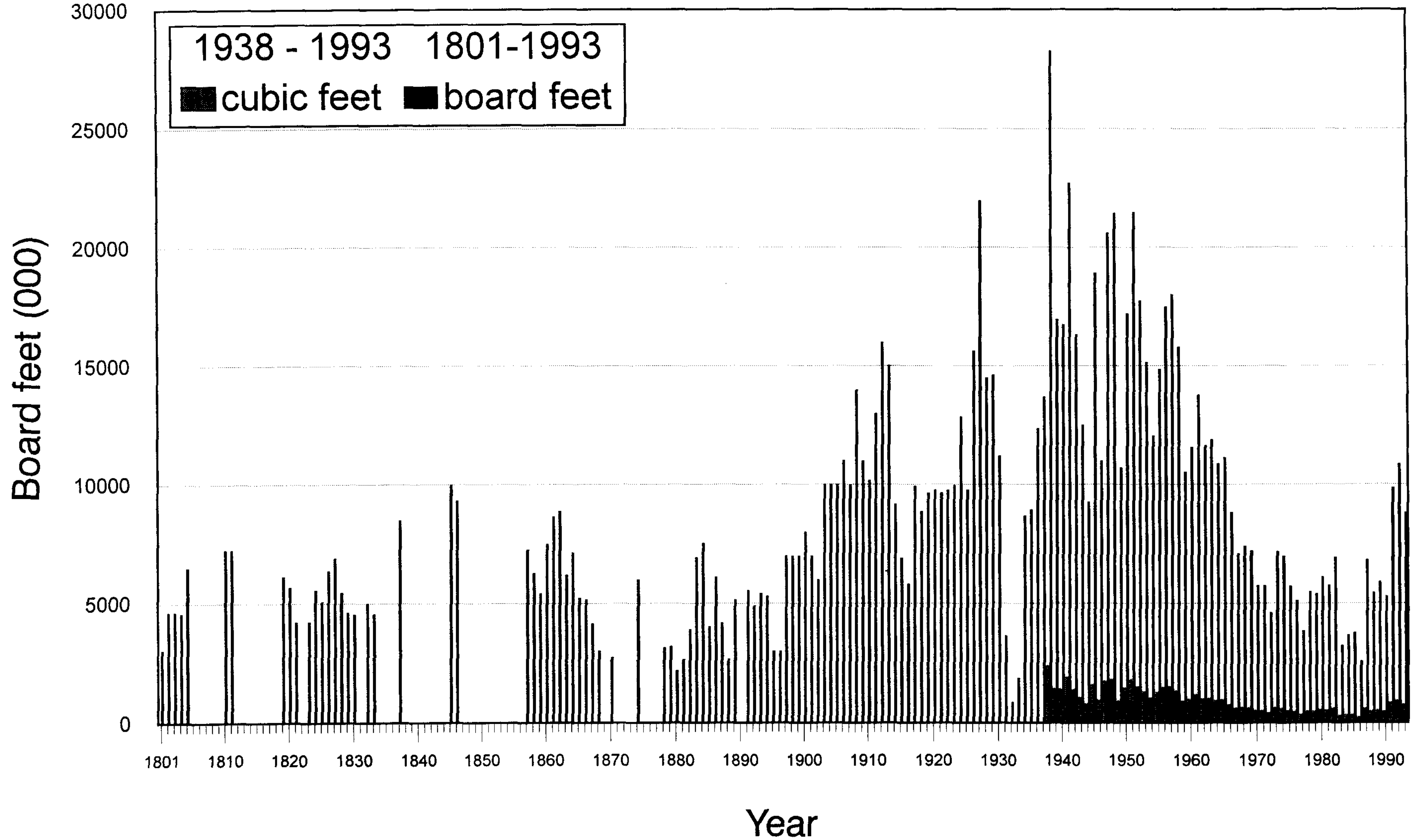

Figure 5—Chronology of mahogany exports from Belize, 1801 to 1993. Data before 1938 were reported in board feet; data after 1938 in cubic feet (a 12 to 1 relation was used to convert cubic feet to board feet). Reexports, when specified, were excluded. In 1930, 1933–36, and 1977–93, mahogany and cedar exports were grouped together and mahogany was arbitrarily estimated at 95 percent of the total (Bolland 1977, Bristowe and Wright 1888, Central Statistical Office 1994, Grant 1976, Hooper 1887, Hummel 1925, Metzgen and Cain 1925, Overseas Development Administration 1989, and colonial annual reports from 1888–94 and forestry annual reports).

Table 4—Estimates of mahogany densities and volumes in Belize

Location of survey (date)	Size	Estimate		Source
		Volume	Density	
	ha	*m³/ha*	*Stems/ha*	
Large areas of cut-over forest (1920's) ≥15 cm d.b.h.	--	--	4.0	Oliphant 1928a
Silkgrass Reserve (1920's)				Oliphant 1928a
All sizes	--	--	1.6	
≥58 cm d.b.h.	--	--	0.7	
Freshwater Creek Reserve (1930's–1940's)	29 630	—	4.75	Lindo 1967
<30 cm d.b.h.		--	2.2	
30-60 cm d.b.h.		--	3.2	
>60 cm d.b.h.		--	.3	
Rio Bravo area				
Deciduous seasonal forest		--	1.2–5.0	Wright and others 1959
Hill Bank and Duck Ridge	203 000	--	1.0	Programme for Belize 1992
Chiquibul Reserve 1969–71	184 900			Johnson and Chaffey 1973
≥50 cm d.b.h.		0.2–0.5	--	
≥70 cm d.b.h.		.1– .4	--	
≥3 m in height		--	1.0–5.6	
Forest Reserves: Chiquibul, Columbia, Maya Mountain (1969–75)	96 500			Alder 1993
≥20 cm d.b.h.		4.2	5.9	
≥40 cm d.b.h.		1.0	.4	
≥60 cm d.b.h.		.6	.1	
Forested national lands: Deep River, Cockscomb (1978–81)	108 700			Alder 1993
≥20 cm d.b.h.		4.7	6.0	
≥40 cm d.b.h.		1.5	.5	
≥60 cm d.b.h.		1.0	.2	
Forested private lands: Belize Estates (1975)	98 100			Alder 1993
≥20 cm d.b.h		5.7	7.4	
≥40 cm d.b.h		1.7	.6	
≥60 cm d.b.h.		1.1	.2	

1980, 37 mills (Munro 1989); and by the late 1980's, about 45 mills, with 6 producing 75 percent of the timber products (Overseas Development Administration 1989). Sawmilling is an exceedingly mobile industry (Munro 1989); most mills are old, portable, circular or band mills, which are active part of the year and capable of moving to new felling areas as local timber supplies are exhausted. Sociopolitical pressures to keep the mills operating resulted in a partitioning of forest reserves among numerous small operators, most without designated concession boundaries (Howell 1994). Overcutting of immature trees has been politically convenient but at a devastating cost to Belize's forest resources.

In addition to sawmills, two functioning veneer plants and a large number of small furniture plants are operating (Howell 1994). The largest veneer plant produces plywood with a mahogany decorative face. However, the current trend in the furniture industry is away from mahogany and cedar to other decorative hardwoods.

From 1922 through 1940, forest products (primarily mahogany and cedar) made up 80 percent of Belize's total domestic exports (Stevenson 1941), declining to around 45 percent in the late 1940's, to 25 to 30 percent during the 1950's, and to 15 percent in 1963 (Furley 1968). From 1950 through the early 1980's, mahogany volumes made up from 30 to 50 percent of Belize's total timber production, after which they declined to about 20 percent (Smith 1991). By the 1980's, economically accessible mahogany was scarce.

Mahogany scarcity is also reflected in minimum diameter limits and the time between cutting cycles. During the 20th century, the minimum diameter limits for cutting mahogany declined from 106 to 58 cm in diameter (Munro 1989, Smith 1991), with designated values at 86, 72, and 64 cm at different times (Benya 1979a, Kinloch 1938, Wright and others 1959). Cutting cycles declined from 45 to 10 years (Munro 1989, Smith 1991). As of 1994, mahogany as small as 20 cm in diameter was being cut and exported (Howell 1994).

Certain areas within Belize, however, have been managed for varying periods of time. The forest resources (including mahogany) in these areas are in better condition than those in the remainder of the country:

- The Columbia River, the Maya Mountains, and Cockscomb Forest Reserves where the forests were opened and closed periodically for harvest.
- The Silkgrass and Chiquibul Reserves where research was undertaken but lost when Hurricane Hattie passed through the areas in 1961.
- The BEC properties where the management program carried out from the mid-19th century through the 1970's used larger girth limits and longer cutting cycles.

The forest industry—once the mainstay of the Belizean economy—can no longer rely on mahogany and cedar harvest (Munro 1989). The country's public forest resources are rapidly disappearing—mahogany, pine, and secondary hardwoods (Howell 1994). The limited information available for private forests indicates that they too are being harvested for their remaining stocks of commercial species (Overseas Development Administration 1989).

Silviculture and Management Activities

The Forest Department

In 1886, a visit to the British colony to inspect the forests and the timber trade resulted in a report that recommended forming a forest department (Hooper 1887). The Colonial Research Committee sponsored a second visit with the same objectives in 1921 when mahogany was approaching exhaustion (Gill 1931, Troup 1940). The Hummel report resulted in the appointment of a conservator of forests in 1922 and the formation of a Forest Trust in 1923. Both steps were aimed at conserving crown lands and improving forest harvest and management (Gill 1931, Hummel 1925). Increasing the growth of mahogany on favorable sites and finding markets for secondary woods were two important policy objectives. The lament of Belizean forestry was succinctly summarized as follows: "In a country which has owed its advancement almost entirely to its forest wealth, it is strange that no attempt was made to establish a forest department until after the war of 1914-18" (Troup 1940).

The forestry program, initiated under the Forest Trust in 1923 and continued under the Forest Department in 1935 (Stocker 1924, and Appendix A), operated with limited funding. From the late 1930's through 1959, however, expenditures increased annually in accordance with programmed activities (Frith 1961). The Forest Department's work on mahogany regeneration and the use of girth limits in mahogany harvest, both confined to forest reserves, slowed the deterioration of mahogany resources within the country (Furley 1968). In 1959, a fiscal review of government programs produced a report that led to a drastic reduction in most of the Forest Department's activities (Downie 1959; Frith 1960, 1961; Hall 1973). Currently, with a continued increase in administrative responsibilities, the Forest Department suffers from a lack of the funding and staffing needed to implement its programs (Smith 1991).

As of 1990, Belize could be partitioned into five land categories: private land, 37 percent; leased national land with intent to purchase, 31 percent; undesignated lands, primarily due to lack of access, 3.4 percent; national parks, nature reserves, wildlife sanctuaries, or national monuments, 3.9 percent; and forest reserves, 24.7 percent (Smith 1991). Of the 5670 km^2 designated as 16 forest reserves (fig. 4), 23 percent is productive forest, 38 percent protective forest, 9 percent roadways or stream bank reserves, and 30 percent either noncommercial cover or insufficiently stocked to support commercial logging (Smith 1991). The Forest Department's principal management and research activities, including mahogany improvements (table 5), experimental observations (Appendix B), and research below, were concentrated in four of these forest reserves: Silkgrass, Columbia, Freshwater Creek, and Chiquibul.

Mahogany improvement—Several early surveys of forest land, most of which had been logged for mahogany at long intervals, showed few mahogany stems in the smallest diameter classes (Hummel 1925). Hummel argued that the lack of regeneration would lead to a decline of mahogany and that improving logged-over forests could remedy the situation.

Stand improvement operations aimed at increasing mahogany growth and regeneration were initiated. Mahogany crowns were released by cutting vines and girdling less valuable trees (Oliphant 1928a, Stevenson 1927a, 1927c). In seedling operations, brush and small trees were cut and large trees were girdled to remove competition. Another treatment for seedling improvement involved areas immediately around felled mahogany stumps (Oliphant 1928a). Seedlings thrived, growing 30 to 60 cm within 2 to 3 weeks at the beginning of the growing season (Stevenson 1927a). By 1929, nearly 100,000 seedlings, saplings, and trees had been treated in five forest reserves and two major private holdings (Record 1930). Improvement work was abandoned between 1929 and 1938 because staffing decreased while costs increased (Stevenson 1939). By 1942, more than 1 million stems had received one or more treatments (table 5).

Mahogany improvements were evaluated in the Columbia Forest Reserve in 1944 where seedlings regenerated before the depression had subsequently died (Lamb 1948a). Moreover, in the Silkgrass and Freshwater Creek Reserves, the hurricanes of 1941 and 1942 had altered forest conditions making assessments impossible. Mahogany improvements were abandoned in favor of plantations.

Experimental observations and informal research activities—From 1925 through the mid-1960's, the Forest Department observed mahogany in several forest reserves. Studies included the economics of silvicultural operations, the impacts of natural disasters (hurricanes and insect infestations), and the evaluation of silvicultural treatments (Appendix B).

In the area of economics, the Forest Department collected cost data associated with silvicultural treatments of mahogany—information rarely recorded in the American Tropics. Hurricane impacts and forest responses were noted on several occasions (Appendix B). These observations included amounts of stem damage by species and age class, reductions in tree growth rates, and delays in seed production. In one instance immediately after a storm, planned fellings were delayed to allow mahogany to recover, thus improving the chances for natural regeneration.

Mahogany suffers from infestations by shoot borers, ants, and other defoliators. The amount of damage caused by borers varies locally, and the effects of surrounding shade, species mixtures, and chemical treatments on infestation rates were studied. While ants may be controlled chemically, the shoot borer and defoliating caterpillars are probably best overcome by fast growing trees.

Experiments in the Chiquibul Forest in 1958 and 1959 demonstrated that insect attack may partially explain reductions in mahogany regeneration (Wolffsohn 1961). Applying Aldrin under seed-bearing trees resulted in profuse regeneration; untreated control plots in the same area contained only sparse regeneration. These results suggested that variations in insect populations may account for irregularities in age-class distribution of seedlings. Moreover, the relative abundance of regeneration on large, burned areas may be partly due to the temporary elimination and slow recovery of local insect populations.

The response of mahogany seedlings to different site conditions was also observed. Cleaning underbrush in a residual mahogany stand at one reserve location had little

Table 5—Estimates of mahogany improvements from 1922 to 1942 in Belizean forests [a] [b]

Location and years	Improvements[c] Seedlings	Saplings	Poles/trees	Total	Percent of total
	No. of stems				
BEC[a] 1922–29	--	--	--	146,990	14.5
Columbia River 1926–31	184,104	8,302	703	193,109	19.1
Freshwater Creek 1926–27, 1939–42	4,817	13,475	16,435	34,727	3.4
Middlesex (Manatee) 1926	7,140	100	86	7,326	0.7
Silkgrass 1922–28, 1939–42	574,793	21,166	5,338	601,297	59.4
Sibun-Stann Creek 1924–27	22,720	225	2,166	25,111	2.5
Vaca (Chiquibul) 1925–27	1,284	222	2,531	4,037	.4
Total	794,858	43,490	27,259	1,012,597	100.0

[a] Minimal estimates. Belize Estate & Produce Company (BEC) data are incomplete. Some records group numbers of improved seedlings regardless of species and others indicate improvements without seedling counts.
[b] Sources: Kinloch 1933; Oliphant 1925, 1926, 1928b; Stevenson 1927b, 1929, 1930, 1931, 1940, 1941, 1942, 1943; Stocker 1924.
[c] Seedling improvements: 46 percent first improvements, 43 percent second improvements, and 11 percent third improvements. Sapling improvements: 62 percent first improvements and 38 percent second improvements.

impact on regeneration, while opening the canopy at another site resulted in good seedling crops. Seedling regeneration on an abandoned corn milpa was abundant and varied inversely with distance from seed-bearing trees. Seedlings regenerated well in both a secondary forest protected from fire and an area previously burned. Seedling growth rates, the planting of hybrid mahogany in the forestry arboretum, and unsuccessful provenance trials were also reported.

Planting seedlings in groups or lines in previously logged forests and on abandoned agricultural fields were among the initial recommendations suggested to improve future mahogany stocking (Hummel 1925). The annual reports regularly provided information on the progress of these plantations including areal extent and location, seedling survival, and growth rates (Appendix B). Techniques used to establish plantations included line planting nursery stock in secondary brush, direct seeding mahogany with subsistence crops (taungya), and planting seedlings in small clusters (Anderson groups). Mixed experimental plantings of mahogany with other hardwood species led to preliminary suggestions for suitable associate species.

The first planting program began in 1925 on the Silkgrass Reserve where areas were clear felled during the dry season and planted with seeds at 3- x 3-m spacings (Oliphant 1928a, Smith 1942). Corn was planted with the seedlings to offset costs. The areas were cleaned annually but secondary tree species were not removed. The results were variable and generally unsatisfactory because seed germination was poor. Resowing resulted in little success because the secondary growth had not been opened sufficiently. Similar taungya plantings of mahogany were implemented with local Mayan Indians in the Columbia River Forest Reserve (Record 1930) where, during the 1940's and 1950's, more than 400 ha were planted (Overseas Development Administration 1989). By the mid-1950's, plantations reached an areal extent of 680 ha with nearly 60 percent located on the Columbia River and Silkgrass Forest Reserves. Between 1955 and 1964, the taungya system was used when planting an additional 600 ha of mahogany at Columbia River Forest Reserve (Ennion 1996). Silvicultural techniques tested to release mahogany from competition included cutting climbers, girdling inferior species, thinning saplings, and pruning. Mahogany usually responded favorably to these treatments.

Formal research activities: past and present—The Belize Forestry Department has initiated few formal research studies, including indigenous species trials at Melinda Forest Reserve (Grant's Works A), line planting trials and growth plots at Silkgrass, and the measurement of taungya plantations at Columbia River Forest Reserve. Unfortunately, the first three projects were terminated because hurricanes caused severe damage.

Mahogany research projects reported by the Belize Forestry Department:

Forest reserve	Year(s) established	Brief description of research and results (source)
Melinda	1971	**Indigenous species trial**—Mahogany planted 3 x 3 m on 0.2 ha; Aldrin applied to alleviate ant attack (*Atta* spp.); September 1974 hurricane passed over site; inspection during July 1978 noted that 90 percent of the stems were damaged; inspection in January 1980 found the average mahogany 3 m in height; study terminated (Ennion 1994, Evans 1983)
Silkgrass	1940–54	**Mahogany growth plots**—Seven plots with 102 trees remaining in 1978; mean height growth averaged 0.47 to 0.62 m per year; mean diameter growth averaged 0.56 to 0.77 cm per year; hurricane and shoot borer damage evident; study terminated (Ennion 1994, Evans 1983)
	1976	**Line planting trial**—Mahogany planted with 5 other species in random-block design with 5 replicates, each replicate a line of 5 trees planted at 3-m spacings separated from the next line by 25 trees; cleaned every 6 months for 2 years, then cleaned and measured annually until 1981; hurricane damage in September 1978; inspection in April 1981 determined that height growth and form were poor; trial terminated (Ennion 1994, Evans 1983)
Columbia	1955–64	**Taungya plantings**—Four surviving growth plots of 11 originally established; plots ranging from 0.12 to 0.20 ha, unthinned, 2 dating from 1956 and 2 from 1958; mean diameter growth at 36 to 38 years old, 0.7 to 0.8 cm per year, with growth declining since ages 20 to 25 years old; mean volume growth at 36 to 38 years old, 5.0 to 6.3 m^3 per ha per year in stands with 252 to 288 stems per ha and 2.1 to 2.6 m^3 per ha per year in stands with 119 to 138 stems per ha (Ennion 1994, 1996)

The taungya mahogany plots measured recently in the Columbia River Forest Reserve provide 36 to 38 years of growth data (Ennion 1996). Growth curves for volume (both mean annual increment and periodic annual increment measured in 5-year periods) were extrapolated to estimate a rotation age of 55 years. The taungya system is an inexpensive way to establish plantations that yield satisfactory volume growth with minimum maintenance. Mahogany managed under a selection cut requires many times the area in plantations to produce equivalent yields. When only 23 to 33 years old, the plantation volumes at the Columbia River Forest Reserve were 10 times greater than those managed by selection cut on the BEC properties (Overseas Development Administration 1989).

National Parks and Nature Reserves

The combined areas of Bladen Branch and Rio Grande Nature Reserves, both located in the same general area, and the Chiquibul and Blue Hole National Parks total about 1500 km^2, or 6.5 percent of Belize. In addition, another 350 km^2, or 1.5 percent of Belize, are proposed for protection in six new reserves (Howell 1994). Mahogany resources in these areas should remain protected.

Private Forest Reserves

Rio Bravo Conservation and Management Area (RBCMA)—The British Honduras Company, registered in 1859 by old settler families and a London merchant, became the BEC in 1875, and a subsidiary of the J. Glicksten Property and Investment Trust Ltd. in 1947 (Bolland 1977). The BEC emerged as Belize's predominant landowner by purchasing more than 40 percent of the colony's private property and nearly 20 percent of all property (Bolland 1977, Troup 1940). In the late 1980's, the BEC property was purchased by the Programme for Belize (PfB) for management as the RBCMA (fig. 4). La Milpa Center, the third largest classic Maya site in Belize and many secondary Mayan centers are situated on the RBCMA property (Programme for Belize 1992). During the classic Maya period, virtually all of the RBCMA property was cleared of forest.

Timber exploitation using girth limits began on the BEC property in 1848 and continued intermittently through the mid-1980's. Lands were subdivided into compartments that were cut on 40-year cycles. In 1924, forestry graduates were hired as managers (Troup 1940). Forest cover was maintained throughout the period, and the gaps created by harvest allowed for some regeneration of mahogany.

The managers at BEC were responsible for a network of roads, a seed collection program, a nursery, and species trials. An inventory of the BEC forests in 1972–74 combined with data from growth and yield plots showed that logging only prime species would not be profitable after 1981 because of previous overcutting, logistics, labor costs, and equipment depreciation (Associates in Rural Development 1984). In 1981, girth limits were lowered to maintain the harvest rate which reduced potential volumes in the next cycle (Munro 1989). During much of the time BEC managed these lands, the harvest system was assessed as almost sustainable. Some 200 years of exploitation, however, had depleted the mahogany growing stock. The appearance of sustained production was possible only through sequential reduction of the girth limits (Overseas Development Administration 1989).

The Rio Bravo area (RBCMA properties) occupies 92 600 ha of northwestern Belize in 1993 (Harcourt and Sayer 1996). The PfB, a private, nonprofit, Belizean corporation founded in 1988, currently manages RBCMA properties as a center for basic and applied research. One of PfB's objectives is the economic development of Belize through projects in tourism, agriculture, archeology, forestry, fisheries, and the management of natural resources. Management of natural resources includes producing commercial timber and nontimber (allspice, chicle, xate palm) products, protecting plant and animal resources, and promoting environmental awareness and natural history tourism. The PfB is holding the property in perpetual trust for the people of Belize.

The PfB proposes land management based on the rights and obligations of private land ownership. The PfB property is partitioned into several distinct zones, including nature reserves; wetlands; and areas for conservation research, natural forest management, and special uses. The PfB will develop a land use plan and base forest harvest activities on forest inventories. Several potential management problems have been identified including unauthorized immigration to the area, illicit hunting, timber theft, unauthorized extraction of nontimber products, and looting of archeological sites.

Forest research was initiated in 1994. A 93-ha area was set aside to monitor bird populations. Within this area, several plots will be logged for mahogany and other commercial hardwoods. Researchers will assess logging impacts on wildlife species and the regeneration of mahogany and other timber species.

Other private organizations—Belize has at least 125 km^2 of private reserves under the management of four separate groups founded between 1985 and 1987: Shipstern Nature Reserve, Society Hall Nature Reserve, Community Baboon Sanctuary, and Monkey Bay Sanctuary (Howell 1994). Moreover, three nongovernmental organizations—the Belize Audubon Society (BAS), the Belize Center for Environmental Studies (BCES), and the Belize Zoo (BZ)—are active in environmental programs within the country. Working with the Forest Department, the BAS manages four terrestrial units totaling 430 km^2: the Cockscomb Basin and Crooked Tree Wildlife Sanctuaries and Blue Hole and Guanacaste National Parks. The BCES concentrates on environmental studies and the BZ maintains a collection of indigenous wildlife. Mahogany resources on these properties total 555 km^2, or about 2.4 percent of the country, and should remain protected.

Recent Conservation Efforts

Belize listed mahogany in Appendix III of the Convention on International Trade in Endangered Species (CITES) in November 1995. An Appendix III listing requires that a certificate of origin accompany all exports of mahogany including sawn wood and veneer. In the early 1990's, Costa Rica and the United States proposed listing the genus *Swietenia* in Appendix II (Rodan and others 1992) but withdrew the proposal. The Netherlands resubmitted the proposal in 1994 but it was rejected. If a species is listed in Appendix II, trade volumes must be documented and trade must be compatible with conserving the species at a level consistent with its role in the ecosystems in which it occurs throughout its range. An Appendix II listing does not ban trade; it is designed to avert an Appendix I listing which does ban trade.

Any conservation strategy designed to protect genetic variation in mahogany requires more information on the status of populations (Newton and others 1993b). Although mahogany has declined dramatically in both abundance and size during 300 years of exploitation in Belize, the species still grows in much of the country. Moreover, recent local measures have been adopted to protect mahogany and other important commercial species. In 1992, the Rainforest Alliance certified Belize's New River Enterprises in the Smart Wood Certification Program for the harvest of mahogany and other hardwoods (Ussach 1992). Belize is currently considering a ban on exporting ziricote (*Cordia dodecandra* D.C.) and rosewood (*Dalbergia stevensonii* Standl.) to ensure a constant supply of these hardwoods for its growing handicraft industry (Hernandez 1996). The future of wood industries in Belize depends on conserving timber supplies and practicing sustainable management.

Future Alternatives: Mahogany Conservation and Management

Downie (1959) suggested that Belize, with its large forest estate, should not invest considerable sums of public money in the creation of plantations. In the late 1980's, visiting consultants still viewed plantations as tenuous ventures because extended financial commitments were required and because Forest Department operational budgets remained unpredictable (Overseas Development Administration 1989). Moreover, fires (Wolffsohn 1967), insect pests like the mahogany shoot borer (Newton and others 1993a), hurricanes (table 1), and issues such as land tenure (Howell 1994) would complicate plantation management. The possible exceptions were taungya plantings like those in the Columbia River Forest Reserve and mahogany enrichment plantings in degraded secondary forests (Howell 1994).

If the forests of Belize are to remain a continuous source of timber, management of public and private lands must improve. Because management objectives, forest types, past logging, stocking, and regeneration differ (Wright and others 1959), no one management system is likely to be universally satisfactory. A simple polycyclic system specializing in prime timbers, such as mahogany and cedar and using girth limits and area control by compartments leaves a forest with greater productive potential than does repeated, unsystematic, and sporadic logging of commercial trees. A comparison of the BEC properties during the late 1970's with readily assessable private lands supports this contention. Although management for timber production on BEC lands was better than that on most private lands, the density of harvestable prime timbers declined, albeit at a slower rate.

The majority of the commercial tree species in Belize are shade intolerant after the seedling stage and would probably respond better to a monocyclic management system (Overseas Development Administration 1989). Continued selective logging of the largest specimens removes seed sources, creates openings too small for regeneration, and favors less valuable shade tolerant species (Snook 1992). A revised forest management system aimed at continuous production should be based on the designation of a permanent forest estate for timber production and the development of management plans with a strategy for local industrial needs. The management plans should include inventories, specified cutting cycles, girth limits, intensive yet careful logging leaving scattered superior trees for regeneration, and postlogging inspections (Overseas Development Administration 1989). The future of forestry and the wood-using industries in Belize depends on resolving several critical issues. These issues involve revising forest legislation, improving forest management, increasing expenditures for control measures and research, changing policy on concessions (e.g., favoring larger mills with value-added capacity and increasing public revenues from royalties), developing local and export markets, and increasing value-added and export earnings (Hone 1993, Howell 1994, Overseas Development Administration 1989, Smith 1991, Synnott 1992).

A merchantable mahogany tree in excess of a reasonable girth limit is a rare commodity in Belize today. If mahogany is to play a prominent role in Belize's future, positive steps must be taken to increase its abundance and size in managed forests. In the short run, logging in natural forests should concentrate on other commercial timbers leaving mahogany trees as seed sources. Mahogany enrichment plantings, successful in many other areas in the neotropics (Weaver 1987), should also be considered.

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Appendix A

Chronology of events, mainly Belizean, with implications for mahogany occurrence, exploitation, management, or trade (Bolland 1977, Buhler 1976, Burden 1931, Downie 1959, Gibbs 1883, Hernandez 1996, Hoare 1993, Hooper 1887, Howell 1994, Hummel 1925, Humphreys 1981, Krohn 1987, Mell 1930-32, Melville 1936, Metzgen and Cain 1925, Smith 1991, Stevenson 1933, Ussach 1992).

Date	Event[a]
2500 BC	Age of the oldest Maya site in Cuello, Orange Walk, Belize.
1000 BC -AD 1000	Mayans occupy Belize, leaving a lasting impact on forest resources.
1502	Columbus explores lands bordering the Bay of Honduras for a passage to the Pacific Ocean.
1521–40	Spanish explorers use mahogany for canoes and ship repair.
1524–27	Cortez marches through southern Belize; repairs his ship with mahogany.
1587	Queen Elizabeth boasts that unoccupied Spanish lands are open for colonization by her subjects.
1604	Treaty of London; unoccupied Spanish areas are open for British colonization.
1638	Shipwrecked British subjects (Baymen) first inhabit the mouth of the Belize River (Peter Wallace, reputedly first settler).
1655	Penn (Cromwell's admiral) takes Jamaica from Spain.
1659	Baymen expand northward and conquer logwood sites in Campeche, Mexico.
1660	Bartholomew Sharpe, British pirate, begins to harvest logwood in Belize for sale to England.
1670	Treaty of Godolphin recognizes legitimacy of British settlements in the Caribbean (opens the Americas to British colonization).
1700	Slaves from Jamaica imported to work in logwood operations.
1717	Spanish expel Baymen from the Campeche area of Mexico; Spanish attack Belize several times during the next 40 years in unsuccessful attempts to drive out the Baymen.
1724	Cabinetmakers in England use mahogany.
1750	Mahogany (*S. mahagoni*) scarce in Jamaica; exports to England decline.
1763	Treaty of Paris ends 1759-63 war between Spain and England and allows Baymen to cut and export logwood in Belize but retains Spanish sovereignty over the territory.
1764	Yucatan Governor orders Baymen out of the Rio Hondo area; Jamaica grants Belize a government with a constitution, elected magistrates, and established laws based on the "customs of the Bay," known locally as Barnaby's Code.
1771	Mahogany supplants logwood as Belize's major export..
1774	Loggers fell Belize's largest mahogany.
1779	Spanish attack Baymen in Belize City and eradicate settlement.
1783	Treaty of Versailles allows Baymen to cut logwood from Rio Hondo to Belize River; Baymen reestablish settlement in Belize City.
1786	The Convention of London allows Baymen to cut logwood and mahogany from Sibun River north to Rio Hondo in return for British abandonment of Mosquito Coast logging (e.g., Honduras Coast south to Greytown, Nicaragua) and preserves Spanish sovereignty; settlers from Mosquito Coast arrive in Belize with their slaves.
1788	Mayas attack mahogany works at New River after Baymen encroach on their lands.
1796	The war in Europe ends Spanish presence in Belize.
1797	The British transport rebel Caribs from St. Vincent to the Bay Islands (Ruatan and Bonacca).
1798	Spanish unsuccessfully attack Belize City; Baymen extend land claims by right of conquest west to Garbutts Falls and south to the Sarstoon River.
Late 1700's	A few settlers purchase and consolidate mahogany works into large private holdings.

1800–05	Introduction of oxen for timber extraction.
1803	Construction of Fort George to protect Belize City Harbor.
1805	Baymen prohibit Spanish from cutting mahogany timber.
1821	Mexican and Central American independence from Spain.
1834	Belize abolishes slavery and loggers fear impact on timber extraction.
1848–59	War of the Races (Castes) in Yucatan, Mexico, sends 15,000 mestizos into northern Belize and introduces sugar cane.
1850's	Mahogany trade declines when European ship builders substitute iron for wood.
1855–61	Laws encourage British investors to acquire large Belize estates.
1857	Indians invade Belize, seize mahogany works, and demand ransom.
1862	Belize settlements formally become a British colony.
1875	Belize Estate & Produce Company purchases mahogany lands from Hoare family in London (sells to Glicksten Property and Investment Trust, Ltd. in 1942).
1887	Hooper report describes the history of Belizean logging and calls for the establishment of a forest department.
1900	Belize begins to export mahogany to the United States.
1910	Measurers of Wood legislation passes to ensure proper revenue collection.
1914–18	World War I temporarily impacts mahogany exports.
1920's	Fine mahogany exports, previously shipped to the London market, arrive at North American markets.
1920's	Tractors facilitate log skidding.
1922	Hummel report describes Belizean forests and logging, the state of forest industries and trade, and reiterates the need for a forest department.
1922	The Colonial Research Committee names Hummel the first conservator of forests and he establishes the first of 15 forest reserves.
1923	Hummel initiates the Forest Trust and annual forestry reports begin.
1924	Belize Estate & Produce Company hires a qualified forester to manage properties.
1927	Forests Act provides a forest reservation process, prohibits activities without a license, and controls exploitation and revenue collection.
1930–32	Depression temporarily impacts mahogany exports.
1933	Belize Estate & Produce Company installs first sawmill in Belize City; mahogany logs no longer for export.
1935	Forest Department replaces Forest Trust as forestry administration unit.
1940's	Road construction facilitates log transport; World War II.
1945	Private Forests legislation provides for increased control over cutting prime timber species on private property.
1959	Downie report reorients forestry activities away from investments in plantations and subsequently impacts. forestry research and management.
1980's	Environmental concerns and legislation includes the Wildlife Protection Act in 1981 and the National Parks System Act in 1981.
1981	Belizean independence.
1988	Belize installs the first veneer mill.
1992	New River Enterprises harvests mahogany and secondary hardwoods according to Rainforest Alliance's "Smart Wood Certification Program."
1995	Belize requires a certificate of origin for mahogany export by listing its national tree on the Convention of International Trade in Endangered Species of Wildlife and Flora.
1996	Government considers a ban on exports of ziricote (*Cordia dodecandra*) and rosewood (*Dalbergia stevensonii*) to enhance the local handicraft industry.

[a] The terms Belize (formerly British Honduras), Belize City (formerly St. Georges), and Baymen (e.g., British settlers or loggers) are used for consistency in this appendix.

Appendix B

Brief descriptions by topic and location of major management activities and experimental observations on mahogany in Belize from 1924 through the mid-1960's (information collected from annual reports).

Economics

Silkgrass Forest Reserve:

- Mahogany seedling improvement costs are outlined (Stocker 1924). Subsequent reports contain the costs of different mahogany silvicultural operations on several forest reserves.

Fire Control

Silkgrass Forest Reserve:

- Protection of mahogany trees is initiated (Stevenson 1930) and later extended to other species and reserves.

Hurricanes

Freshwater Creek Forest Reserve:

- Seed pods are absent 2 years after the 1941 hurricane; regeneration is observed along the roadside (Stevenson 1944).
- Very few mahogany in hurricane-blown forest recover sufficiently to produce seed 3 years after the 1942 storm; those in an adjacent pasture contain numerous capsules. Diameter growth also varies: trees in the forest average 0.3 cm per year, whereas those in the pasture average 1.2 cm per year (Lamb 1945).
- Mahogany trees in natural forest do not show an increase in diameter growth until 4 years after the 1942 hurricane (Lamb 1947a).
- The posthurricane restriction of fellings to dead and damaged mahogany trees on 4 ha of good pre-hurricane mahogany forest yields an average regeneration of 26 trees per ha under 4.5 m tall; results justify the policy of restricting fellings of undamaged mahogany until adequate regeneration is attained (Lamb 1949).

Silkgrass Forest Reserve:

- Availability of mahogany seed is limited after the hurricanes of 1942 and 1945 (Lamb 1945).

Stann Creek District:

- Serious damage is detected on 63 percent of the mahogany trees 6 months after the 1961 hurricane (Frith 1964).

Insects

Chiquibul Forest Reserve:

- Brush under mahogany seed trees in natural forest is cut and burned on three small plots to stimulate regeneration; insects consume the seeds (Frith 1959).
- The 1958 plantings of teak and mahogany in mixture to provide lateral shade and reduce shoot borer infestation is unsuccessful and produces a rather awkward mixture from the standpoint of silviculture and utilization (Frith 1961).

Columbia River Forest Reserve:

- Shoot borer attack varies from 10 to 60 percent in 1928 taungya plantings (Kinloch 1933).

Silkgrass Forest Reserve:

- Drastic removal of overstory results in insect infestation; dense cover stagnates mahogany seedlings; and broken canopy overstory appears best (Oliphant 1926).

- Experimental planting of mahogany with six hardwood species is initiated on 0.65 ha to explore an inexpensive way to avert shoot borer damage (Stevenson 1939).

General:

- Trials are initiated to control mahogany shoot borer using the systemic organic insecticides Pestox and Metosystox as root and bark sprays; the effects are too short lived to prevent infestation (Frith 1960, 1961).

Seedling Improvement and Regeneration

Chiquibul Forest Reserve:

- Underbrush cleaned in 1954 on 10 ha of a residual mahogany stand (trees <73 cm in diameter) heavily logged from 1939 to 1946; little regeneration after 1 year (Bird 1994; Cree 1954, 1955).
- Release of mahogany saplings from 1954 to 1959 in forest damaged by fire in 1945; stocking varied from 60 to 450 saplings per ha; by 1960, mahogany and cedar regeneration covered 1520 ha (Bird 1994; Cree 1955, 1956, 1957; Frith 1958, 1959, 1960).
- Four small plots of line plantings and provenance trials established in the 1970's; discontinued in 1980 because survival and growth were poor (Bird 1994).

Freshwater Creek Forest Reserve:

- After 7 years, an area of 5.5 ha proximate to seed bearers and in fire protected secondary growth contains 5,179 seedlings ≤1.8 m in height, 473 saplings between 1.8 to 5.5 m, and 282 poles ≥5.6 m in height for an average stocking of 1,070 stems per ha (Stevenson 1936).
- An area of abandoned corn milpa to the leeward of mahogany seed bearers contains an average stocking of 1,700 mahogany stems per ha after 10 years compared with a control site with 5 stems per ha; total stocking varies with distance from the forest border as measured in 7 increments of 20 m: 33 percent, 20 percent, 20 percent, 9 percent, 7 percent, 11 percent, and 0 percent (Stevenson 1939).

Melinda (Grant Works) Forest Reserve:

- In 1962, hybrid mahogany, *S. macrophylla* x *S. mahagoni* from Puerto Rico is planted in the Princess Royal Arboretum (Frith 1963).

Silkgrass Forest Reserve:

- Improvements of mahogany seedlings and saplings increase stocks by 70 percent (Stevenson 1930).
- Canopy opening results in good crops of seedlings (Stevenson 1929).
- Mahogany seedlings grow between 0.2 to 0.4 m per year in height and 0.3 cm per year in diameter during 7 years on five plots. Stem mortality varies between 6 and 75 percent over the same period (Stevenson 1936).

Plantations (mainly Taungya)

Columbia River Forest Reserve:

- Seedlings average 1.1 m per year in height growth after 3 years (Kinloch 1933).
- Mahogany grows between 0.6 to 1.4 m per year in height and 0.6 to 1.7 cm per year in diameter during 5 to 7 years on eight plots. Mean annual height growth varies with available light: full light, 1.4 m per year; half light, 1.0 m per year; shade, 0.4 m per year (Stevenson 1936).
- In 1962 and 1963, about 45 ha of mahogany from different seed sources (local, Mexican, and U.S. Virgin Islands) are planted by taungya at spacings ranging from 10 x 1.8 m to 10 x 7.3 m (Frith 1963, 1964).

Freshwater Creek Forest Reserve:

- Nursery stock 6 months old is planted on 0.8 ha of secondary brush in areas where seed trees are absent (Stevenson 1939).
- Mahogany seed is sown in groups spaced 9 m apart within lines cut through 55 ha of hurricane-damaged forest (Frith 1958, 1960).

- Current annual diameter increment for the last 5 years in mahogany taungya plantings about 25 years old: 217 stems between 5.6 and 27.5 cm in diameter average 0.19 cm per year; 41 stems between 14.6 and 27.5 cm in diameter range from 0.24 to 0.39 cm per year (Cree 1954).

Pueblo Viejo (Columbia River Forest Reserve):

- Mahogany's long taproot and lack of side roots makes the planting of 2-year-old nursery stock unprofitable (Lamb 1949).

Silkgrass Forest Reserve:

- Mahogany growth averages between 0.4 to 1.0 m per year in height and 0.40 to 0.92 cm per year in diameter after 7 to 9 years on five plots. Stem mortality varies between 17 and 43 percent over the same period (Stevenson 1936).
- Mahogany plantings are thinned; *Aspidosperma megalocarpon*, *Cordia* sp., *Cupania triguetia*, *Spondias mombin*, and *Vouchysia hondurensis* appear to be suitable associate species for mahogany (Stevenson 1942).
- Mahogany plantations established from 1940-44 total 16.2 ha; the areas are cleaned and the overstory thinned (Lamb 1946).
- In 1956, 8 ha of mahogany are sown in Anderson groups (20 ha also sown at Cubeta); germination is only 40 percent, but no Anderson group fails completely (Cree 1957).

Many forest reserve areas:

- Mahogany seeds dibbled in corn milpas at Silkgrass show good growth (Oliphant 1928a); trials later extended to Columbia (Stevenson 1930), Freshwater Creek (Kinloch 1933), Commerce Bight (Lamb 1948a), Quam Bank and Stann Creek (Lamb 1949), and other areas. The Silkgrass taungyas planted in mahogany and other hardwoods total 25 ha by 1939 (Stevenson 1940). Plantations are at their maximum areal extent on several different reserves between 1949 and 1958, when 680 ha are reported (in ha): Toledo District - Pueblo Viejo, 71; Machaca Creek, 28; Topco, 12; Columbia River, 284; Stann Creek area - Silkgrass, 122; Quam Bank, 6; Cayo District - Augustine, 27; Maria Camp, 24; Iguana Creek, 61; Cubeta, 43; and Freshwater Creek, 2 (Cree 1953, 1954, 1955, 1956, 1957; D'Silva 1952; Frith 1958, 1959). Continued planting at Columbia increases its total area in taungya mahogany to about 600 ha by 1965 (Frith 1960, 1961, 1962, 1963, 1964).

Release, Thinning, and Pruning

Deep River Forest Reserve:

- Diameter growth rates for 2,202 mahogany trees $\leq$78 cm in diameter on 860 ha of forest exploited 8 years earlier, then released by climber cutting, show differences in diameter growth by forest type and number of measured trees: cohune ridge, 0.91 cm per year (381 trees); broken cohune ridge, 0.79 (690 trees); broken ridge, 0.58 (861 trees); high botan ridge, 0.75 (183 trees); and broken pine ridge, 0.36 (87 trees) (Lamb 1946).

Freshwater Creek Forest Reserve:

- Girdling inferior species and cutting vines result in greater mahogany leaf growth, a response that is slower in older trees (Stevenson 1929).
- Mahogany plantations established in 1928-33 are pruned in 1943; a 1942 thinning of dominant trees in the same plantation increases diameter growth by 2.5 to 5.0 cm per year (Stevenson 1944).

Silkgrass Forest Reserve:

- Girdling large trees results in vine growth and damages regeneration when trees die (Stevenson 1936).