B200 FCFR SFM Evaluation Report 2014 - 2021

Sustainable Forest Management & Rehabilitation Project

Freshwater Creek Forest Reserve, Belize, Central America

Evaluation Report 2014 - 2021

(February 24, 2022)

International Tropical Conservation Fund

With the financial help of Precious Forest Foundation

Abbreviations

MAFFESDISR	Ministry of Agriculture, Fisheries, Forestry, the Environment and Sustainable Development and Immigration Services and Refugees
FD	Forest Department of Belize
ITCF	International Tropical Conservation Fund
CSFI	Corozal Sustainable Future Initiative
PFF	Precious Forest Foundation
HAFL	School of Agricultural, Forest and Food Sciences (BFH / Bern University of Applied Sciences)
WSL	Swiss Federal Institute for Forest, Snow and Landscape Research
FCFR	Freshwater Creek Forest Reserve
NEBC	North-eastern Biological Corridor
SCMA	Shipstern Conservation and Management Area
HCNP	Honey Camp National Park
PFE	Permanent Forest Estate
SFM	Sustainable Forest Management
DBH	Diameter at breast height
RIL	Reduced impact logging
NTFP	Non-Timber Forest Products

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Content

1 Abstract

Fig. 1a *Sunrise at Freshwater Creek forest reserve (2020)*

Between 2014 - 2020, a Sustainable Forest Management Pilot Project was implemented at the Freshwater Creek Forest Reserve in Belize, Central America. The project aimed at zoning this permanent forest estate (PFE) into two main priority areas, namely High Conservation Value areas (HCV) and near-natural production forest zones, while in parallel implementing a forest inventory program. Within Freshwater Creek, the future production forests were found to be in serious need of rehabilitation, as the area was in most parts in a degraded state after years of over-extraction. This extraction was clearly carried out without silvicultural measures to allow for proper regeneration, nor any planning towards future extraction.

Over the course of the project, the CSFI team was trained in various topics pertaining to sustainable forest management (SFM) and reduced impact logging (RIL). These are summarized in this evaluation report. During the course of this project, major changes to land tenure occurred: in 2019, after more than five years of efforts, a 20-year old idea to create a biological corridor between Freshwater Creek and Shipstern came to fruition. The North-eastern Biological Corridor of Belize (NEBC) is now officially declared, and ensures long-term ecological connectivity in the region. The future management and objectives of the NEBC complex are currently being evaluated and realigned, and although the Freshwater Creek Forest Reserve has ceased to exist as such, the Corridor will include several multiple use areas allowing for sustainable forest management.

The 2014-2020 project allowed for the gathering of information about the forests of Freshwater Creek, the testing of various methods in the field, a much better knowledge on local Mahogany phenotypes and their cultivation, and, last but not least, the transfer of know-how on how to approach modern and sustainable silviculture. This will be a huge asset towards the future implementation of sustainable management of forests within the multiple-use zones of the new North-eastern Biological Corridor of Belize.

Keywords: PFE, SFM, forest inventory, silviculture, HCV areas, biological corridor, near-natural production forest, Belize

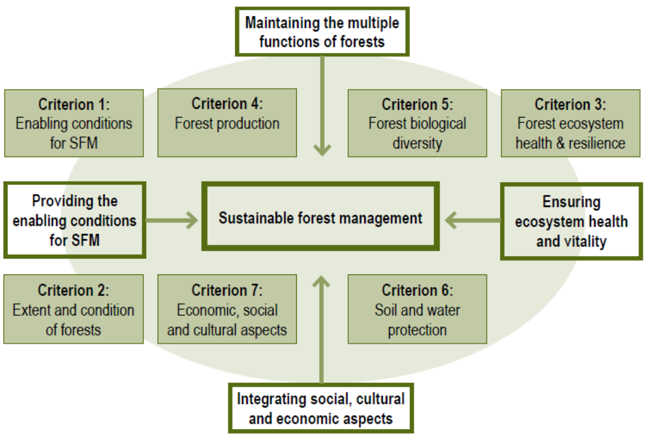


Fig. 1b ITTO defines sustainable forest management as: "*the process of managing forests to achieve one or more clearly specified objectives of management with regard to the production of a continuous flow of desired forest products and services without undue reduction of its inherent values and future productivity and without undue undesirable effects on the physical and social environment*".

2 Introduction

Fig. 2a *FCFR Forestry Team 2017*

This Sustainable Forest Management Evaluation Report (2014-2020) and the SFM Project implemented at Freshwater Creek Forest Reserve (FCFR) in Belize, Central America, are both structured along the ITTO's recommended concept: "Criteria and Indicators for the Sustainable Management of Tropical Forests, ITTO, 2016". Overall indicators pertaining to the management of protected areas, or indicators not yet relevant to the SFM project are not included in this report. Specific ITTO terminology for SFM used in the report can be found in Appendix 13.1.

The 13,400 ha FCFR was established by the British colonial administration in 1923 and has been managed by the Forest Department of Belize (FD) since the country's independence in 1981. Unfortunately, during the 20th century, valuable timber species have been extracted under countless, short term and intensive logging concessions, and also more recently so, in contrast to the fact that Belize's National Protected Areas System Plan and the IUCN Category 6 "Forest Reserves" both state that natural resources can or should be managed for timber and non-timber forest products according to sustainable criteria and measures to benefit the UN SDGs of local communities or livelihoods.

On May 13, 2013, the Belizean NGO "Corozal Sustainable Future Initiative" (CSFI), created in 1989 by the International Tropical Conservation Fund (ITCF) and financially supported by the same since its inception, signed a 40-year co-management concession with the Government of Belize for the management of Freshwater Creek Forest Reserve (FCFR). The initial step undertaken was the zoning of this permanent forest estate (PFE) into two main priority areas, namely High Conservation Value areas (HCV) and near-natural production forests. For the latter, various SFM pilot projects on forest inventory or silvicultural measures were developed and implemented over a span of six years, between 2014 and 2020. These included the tending of young forests, thinning and enrichment plantings, with the main target species being Mahogany (*Swietenia macrophylla* King). In addition, law enforcement, flora and fauna monitoring, environmental education as well as sustainable tourism programs were also implemented in the area, but these were not included in this report. The SFM project's intention is to provide a practical demonstration model for ecologically, economically and socially oriented sustainable forest management in Belize and Central America.

The vision behind the project is the eventual development of a professional forest service for FCFR as well as a competence center for sustainable forestry based on best practices in national and international SFM. Through nature-based silvicultural measures, the project at FCFR should provide the basis for a scientifically sound, sustainable, forest-based local value chain in an ecologically rich system. To achieve this, partnerships were established with various national and international institutions and partners, and implementation was made possible thanks to the invaluable financial support received from the Precious Forest Foundation.

3 Context

3.1 Project perimeter

Fig. 3.1a *Overview map with Belize and the NEBC on the Mesoamerican Yucatán Peninsula*

The project perimeter is located on the Yucatán Peninsula in the North-East of the 23,000 km^2 Central American country of Belize (Fig. 3.1a). Originally, this area was part of the largest contiguous rainforest in Mesoamerica, the "Selva Maya". Today, however, it is mostly separated from the Selva Maya by agricultural and settlement areas, with only few natural corridors left between the two. With 410,000 inhabitants, Belize is comparatively only sparsely populated (17 inhabitants / km^2). The original project perimeter of the years 2014 - 2019 (Fig. 3.1b) was extended in 2020, through the creation of a connective corridor between the protected areas involved (Fig. 3.1c).

More information about the project perimeter can found in the interactive Web report: https://arcg.is/1Hrvb51

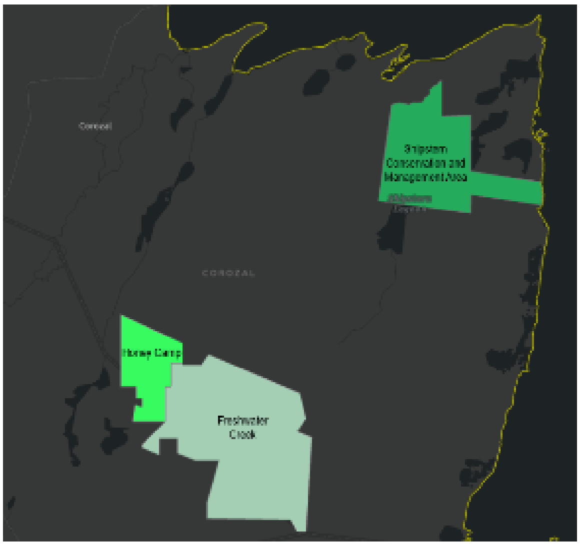


Fig. 3.1b *Project perimeter 2014 – 2019*

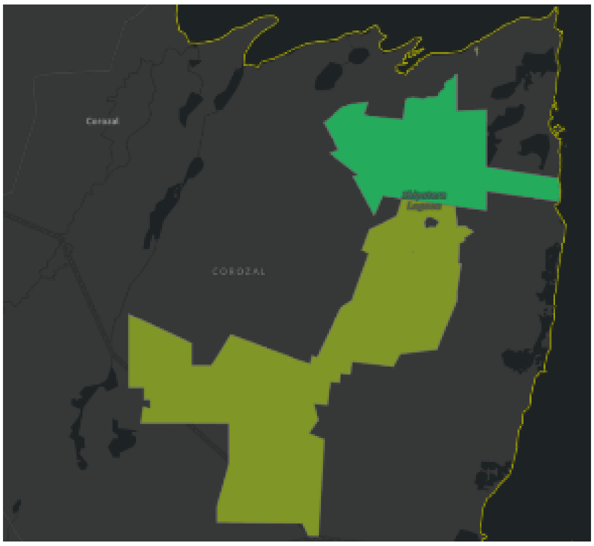


Fig. 3.1c *Project perimeter 2020*

3.2 Climate and location

Belize is located in the outer tropics between latitudes 15º 45' and 18º 30' north and 87º 30' and 89º 15 west. The average annual temperature varies monthly from 24 to 29 degrees Celsius (Fig. 6). The annual climate of Belize is characterized by distinct rainy and dry seasons. In the North of the country, the average annual rainfall (1981-2020) is about 1524 mm, while in the South, it exceeds 4000mm. The increase in precipitation from north to south is also observed within the ecosystems of the corridor, although not to the same extent. Detailed information about climate, location and geology can be found in the documents pertaining to Shipstern, in References: Shipstern Nature Reserve – Management Plan 2011-2016

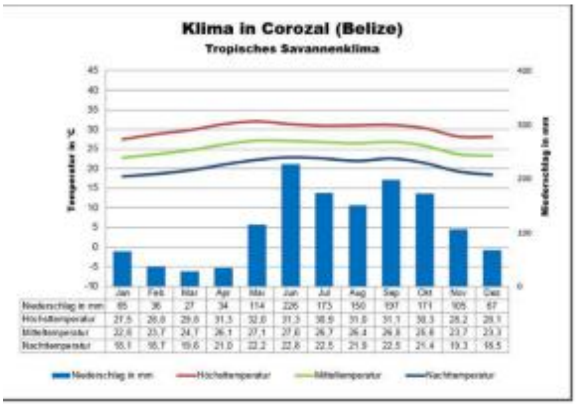


Fig. 4.3a *Annual climate chart for Corozal Town*

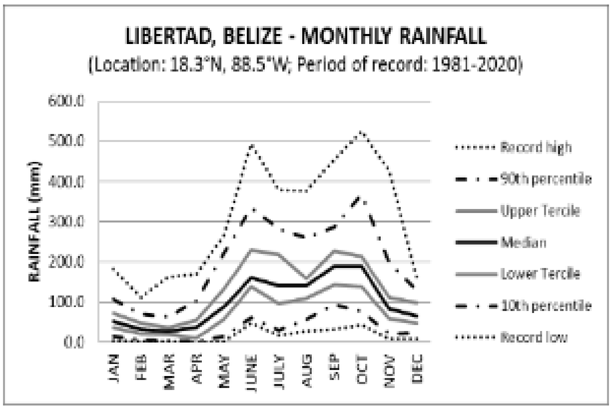


Fig. 4.3b Annual climate Libertad (1981 – 2020) (http://nms.gov.bz)

Relevant for local ecosystems, agriculture and forestry are the significant differences in average precipitation between 1981 and 2020 (Libertad, Fig. 7). The impacts of global climate change with changes in precipitation patterns or the increase of extreme events as well as the reduced resilience of forest ecosystems are likely to be regionally amplified by fragmentation and conversion of natural forests. The project perimeter being located in the Caribbean Hurricane Zone, 16 hurricanes as well as countless tropical storms have impacted forest ecosystems since the 1930s:

- 1931 “Storm Five”, cat. 4, deadliest hurricane in Belizean history
- 1955 Hurricane “Janet” cat. 5 hit hard in the Corozal area, with massive flooding
- 1961 Hurricane “Hattie” cat. 4, 400 casualties, which triggered the creation of the new capital Belmopan
- 1998 Hurricane “Mitch” cat. 5, heavy impact in Central America (ca. 11K casualties), less so in Belize thanks to high forest cover and no landslides.
- 2001 Hurricane “Iris”, cat. 4, heavy losses of livestock
- 2007 Hurricane “Dean” cat. 5, a lot of damage on houses & trees in Corozal district

3.3 Geology and Lithology

Bedrock under the North-eastern Biological Corridor are mostly limestone. Soils are often very dark and shallow, becoming somewhat deeper at swamp edges. Pronounced dry seasons often cause shallow soils to dry out extensively. Most soils are neutral or alkaline, containing significant amounts of calcium and magnesium, and to a lesser degree also phosphorus and potassium.

The soils of the marshes consist in sand and clay, and are regularly flooded with salty or brackish water. They often form the basis for large stands of mangroves (especially *Rhizophora mangle*), whose roots hold the soil together.

The north of Belize is very flat, with hardly any surface rivers to be found. Ponds and lakes are also rare. The landscape is however dotted with cenotes, i.e. sinkholes filled with water and connected with underground aquifers. They are often the only access to fresh water during the annual dry season.

3.4 Governance

3.4.1 National Protected Area System (NPAS)

An impressive part of Belize is under protection, with various categories, statuses and management structures. 769`093 hectares of terrestrial habitats and 159`030 hectares of marine areas, all national lands, are officially protected. In addition, 128,535 ha of private nature reserves exist, and are officially recognized as such in the National Protected Areas System (NPAS) of Belize. In total, 34.9% of the country's terrestrial area is protected. The Corozal Sustainable Future Initiative has managed or co-managed three of these protected areas for many years: Shipstern NR (since 1990), Honey Camp NP and Freshwater Creek FR (sine 2013).

Shipstern Nature Reserve was created in 1990 by the International Tropical Conservation Foundation, a sister NGO of the Papiliorama Foundation Kerzers (CH) and the Royal Burgers' Zoo in Arnhem (NL). On October 31, 2012, this private protected area was recognized as a site of national importance, included in a trust in perpetuity and renamed the Shipstern Conservation & Management Area. In 2020, Shipstern was extended by a further 3,467 hectares, through the purchase of an adjacent parcel.

The Freshwater Creek Forest Reserve (FCFR) was declared by the British colonial administration in 1923 and has been managed by the national Forest Department (FD) since the country's independence in 1981. On May 14, 2013, CSFI signed a co-management agreement for the management of FCFR with the Government of Belize, an agreement allowing for the sustainable management of timber and non-timber products. The same year, CSFI entered a similar co-management agreement for the Honey Camp National Park, to be managed as an IUCN category II park, excluding human interventions in the natural development of forest ecosystems.

Name	Area (ha)	Kategory	IUCN Category	Legislation	Objectives	Activities	Manag. Auth.
Honey Camp	3`145	National Park	2	National Park System Act	To protect and preserve natural and scenic values of national significance for the benefit and enjoyment of the general public.	Research, education, tourism	Forest Department
Freshwater Creek	13`369	Forest Reserve	6	Forest Act	To protect forests for management of timber extraction and/or the conservation of soils, watersheds and wildlife resources	Research, education, tourism, commercial natural resource management and extraction (timber and NTFP)	Forest Department
Shipstern (SCMA)	11`141	Private Protected Area	2	Trust agreement	To complement the national lands through provision of connectivity, priority species protection, and improved ecosystem representation.	Research, education, tourism, sustainable extraction	CSFI

Tab. 3.4.1 *CSFI managed protected areas: status and governance at start of project.*

3.4.2 North-eastern biological Corridor Belize (NEBC)

In February 2018, the Government of Belize agreed to the creation of the North-eastern Biological Corridor. This new corridor, encompassing both the Freshwater Creek Forest Reserve, the Honey Camp National Park and parcels of land acquired by CSFI, joins with the southern border of the Shipstern Conservation and Management Area to form one of the larger corridors ever created in Central America. As such, the former statuses of FCFR and HCNP are no longer valid but remain the property of the Government of Belize, while the SCMA remains a private protected area under trust in perpetuity. The co-management of the corridor has been entrusted to CSFI, for an initial period of 20 years. Surveillance and monitoring of the corridor are carried out by CSFI rangers, often in collaboration with the Police Department, the Belize Defense Force and staff of the Forest Department of Belize.

4 Extent and condition of forests

4.1 Belize's forests

Belize is one of the most forested countries in Central America and the Caribbean. Nevertheless, deforestation and degradation of unprotected forests has been steadily increasing over the past decades. According to Global Forest Watch data, Belize has cleared approximately 235`000 ha of semi-natural forests between 2001 and 2019, representing a 13% decrease in forest area and 75.5 Mt of CO2 emissions. The ratio between temporary deforestation with subsequent reforestation (slash and burn agriculture) and permanently converted agricultural areas can unfortunately not be interpreted from these data. In 2020, the Forest Department published a REDD+ document with official reference data of forest and CO2 emissions over the period 2001 - 2015 (see references).

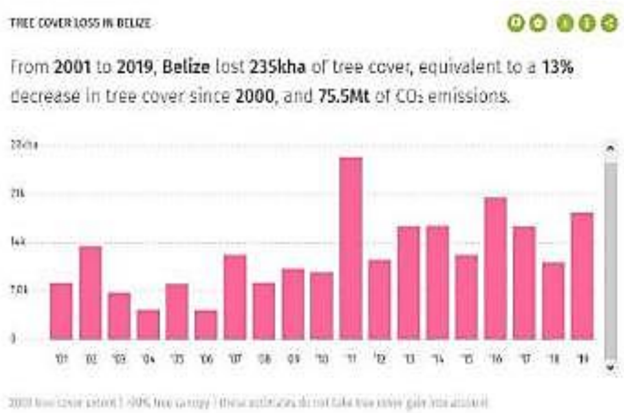


Fig. 4.1a *Tree Cover Loss in Belize 2001-2019 (globalforestwatch.org)*

Fig. 4.1.b *Eastern border of the FCFR reserve (2016)*

4.2 Permanent forest areas in the northeast of Belize

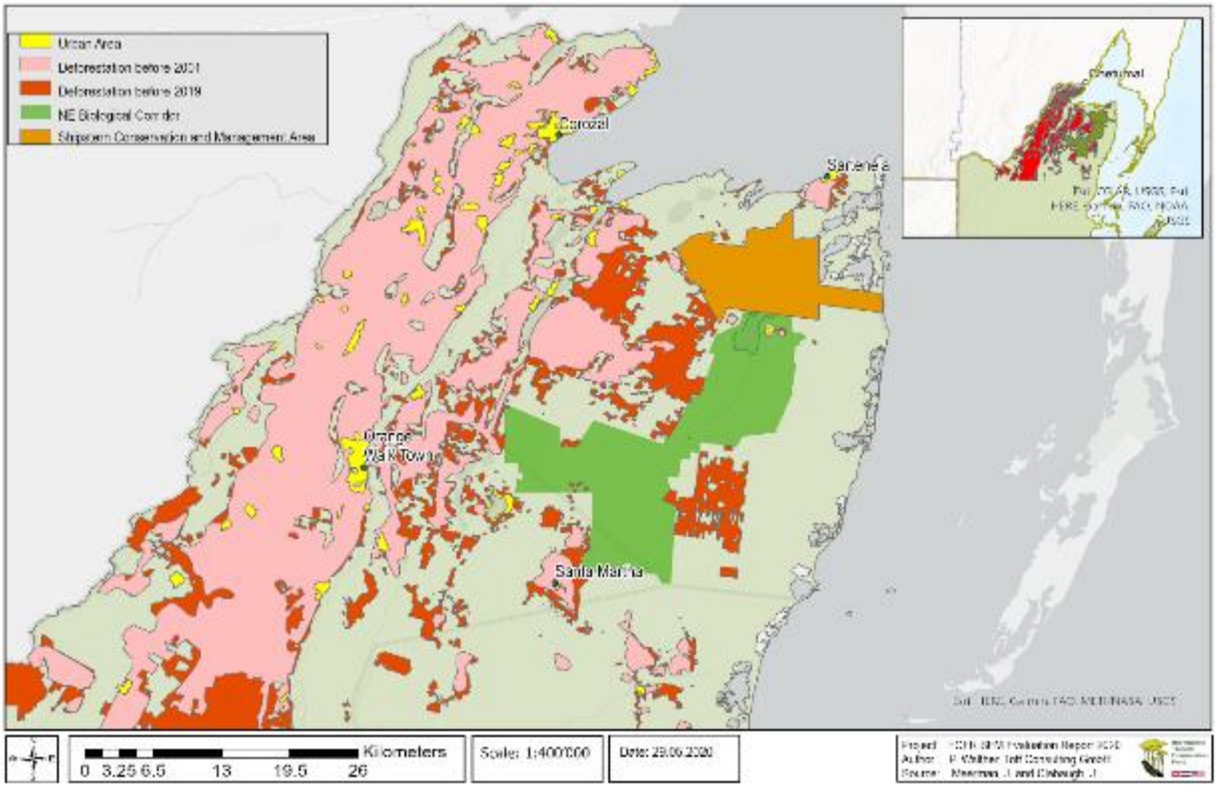


Fig. 4.2 *Deforestation and the NEBC / Shipstern Complex in northern Belize*

The North-East of Belize is seeing a strong development of agricultural areas and lowland rainforests are under heavy anthropogenic pressure. In recent decades, large areas of forest have been converted to agriculture and to a lesser degree to urban area (Fig 4.2). The remaining forests are fragmented and degraded to varying degrees, and now probably also affected by climate change.

4.3 CSFI Forest Management Unit (FMU)

4.3.1 Shipstern Conservation and Management Area (SCMA)

Fig. 4.3.1a *Sunset view from the tower at Shipstern Headquarter (CSFI, 2014)*

Changes to the protected area

In 2020, the total area of the Shipstern and Conservation Management Area increased in size, from 8'387 to 11`141 hectares, thanks to the purchase of a large additional parcel to the West (Fig 4.3.1b). This helped increase the area protecting semi-evergreen and semi-deciduous Yucatan forests, so far under-represented within Shipstern, while also becoming very scarce in Belize. Shipstern is home to extensive lagoons, wetlands and mangroves, while higher grounds are occupied by Yucatan dry forests, unique to Belize and of particular ecological importance (Fig. 4.3.1c). Shipstern's forests were almost completely destroyed by Hurricane Janet in 1955 and have recovered more or less undisturbed since then. Hurricane Mitch caused significant canopy damage in 1998, but forests recovered at an astonishing speed. Because of Hurricane Janet, forests within Shipstern are still regenerating, with a few rare pre-hurricane emergent trees still standing. Detailed information on the vegetation patterns of Shipstern can be found in “The Vegetation of Shipstern Nature Reserve (C.F.A. Bijleveld, 1998) and the Shipstern Nature Reserve – Management Plan 2011-2016 (see references).

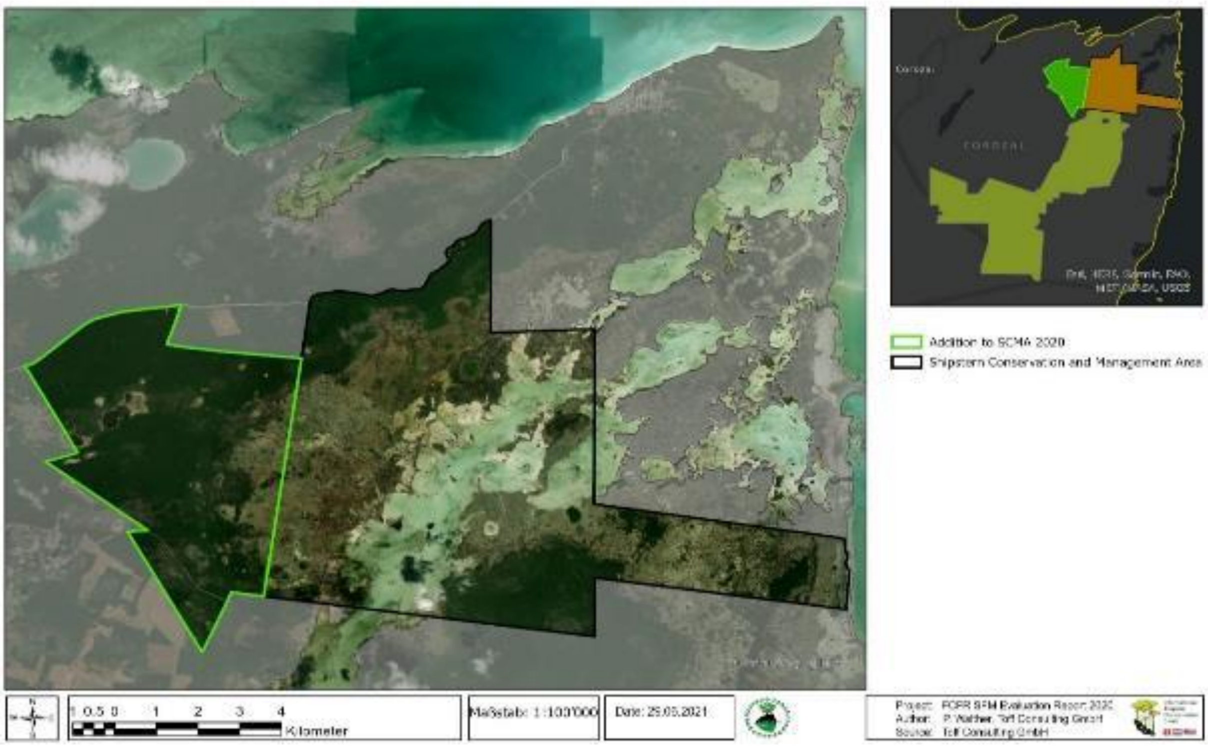


Fig. 4.3.1b *Changes in protected area size, Shipstern Conservation and Management Area (2020)*

Ecosystems and forest communities

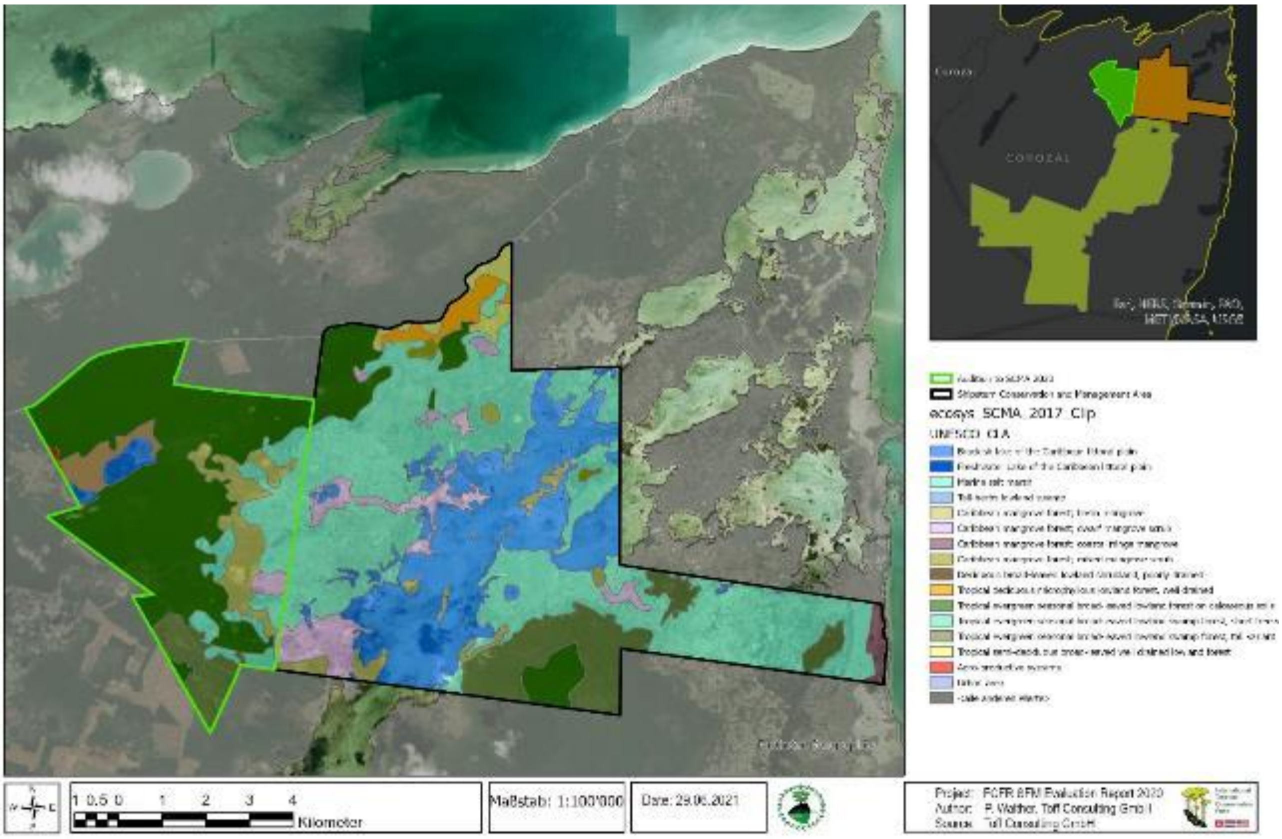
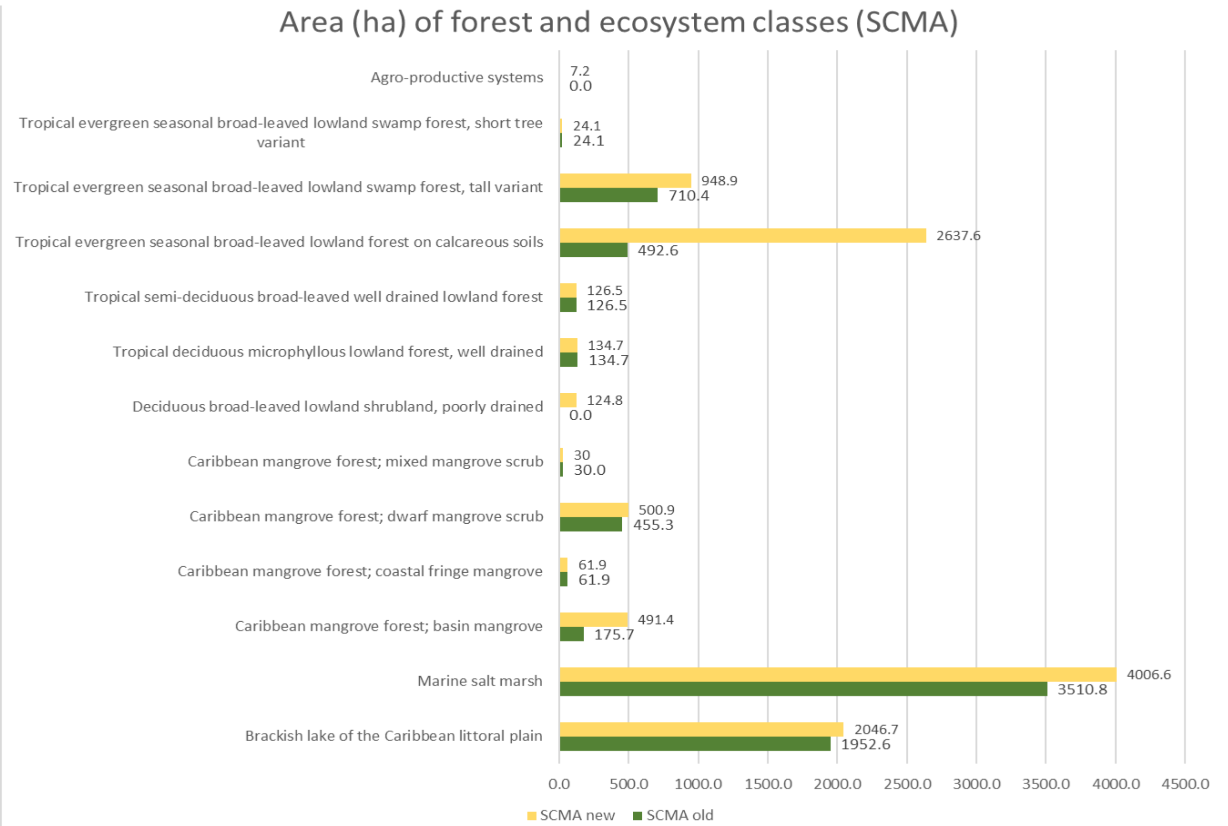


Fig. 4.3.1c *Ecosystems and forest communities of the SCMA (J. Meerman and J. Clabaugh, 2017)*



Tab. 4.3.1 *Area of SCMA ecosystem classes before and after 2020 (Data source: J. Meerman and J. Clabaugh, 2017)*

4.3.2 North-eastern Biological Corridor (NEBC)

Fig. 4.3.2a *Sunrise over the North-eastern Biological Corridor (Freshwater Creek Area, 2020)*

Changes to the protected areas

The area under co-management with CSFI consisted, before 2020, in the Honey Camp National Park (3`145 ha) and the Freshwater Creek Forest Reserve (13`369 ha), for a total of 16`514 ha. Encompassed into the new North-eastern Biological Corridor of Belize, the total area under protection is now 28`275 ha (Fig. 4.3.2b).

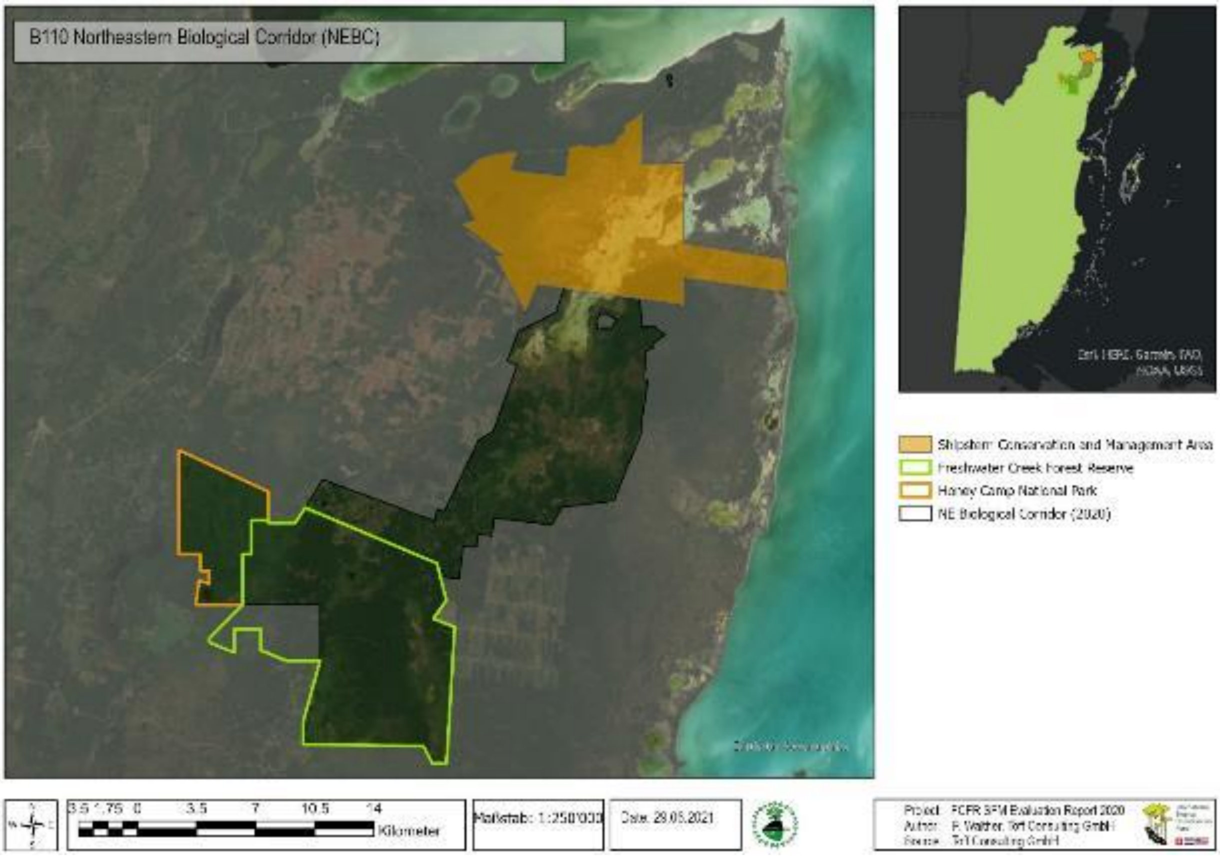


Fig. 4.3.2b *Change in protected areas of the North-eastern Biological Corridor (2020)*

Ecosystems and forest communities

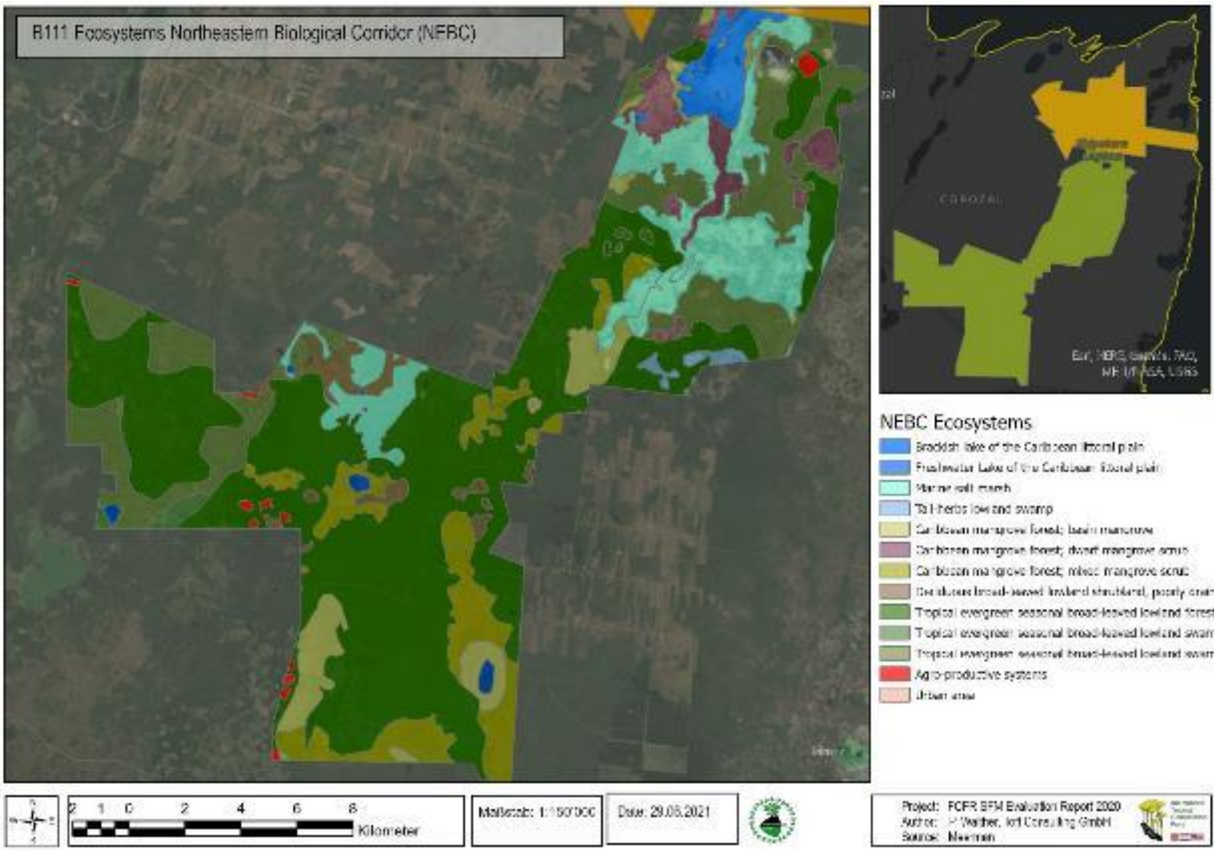
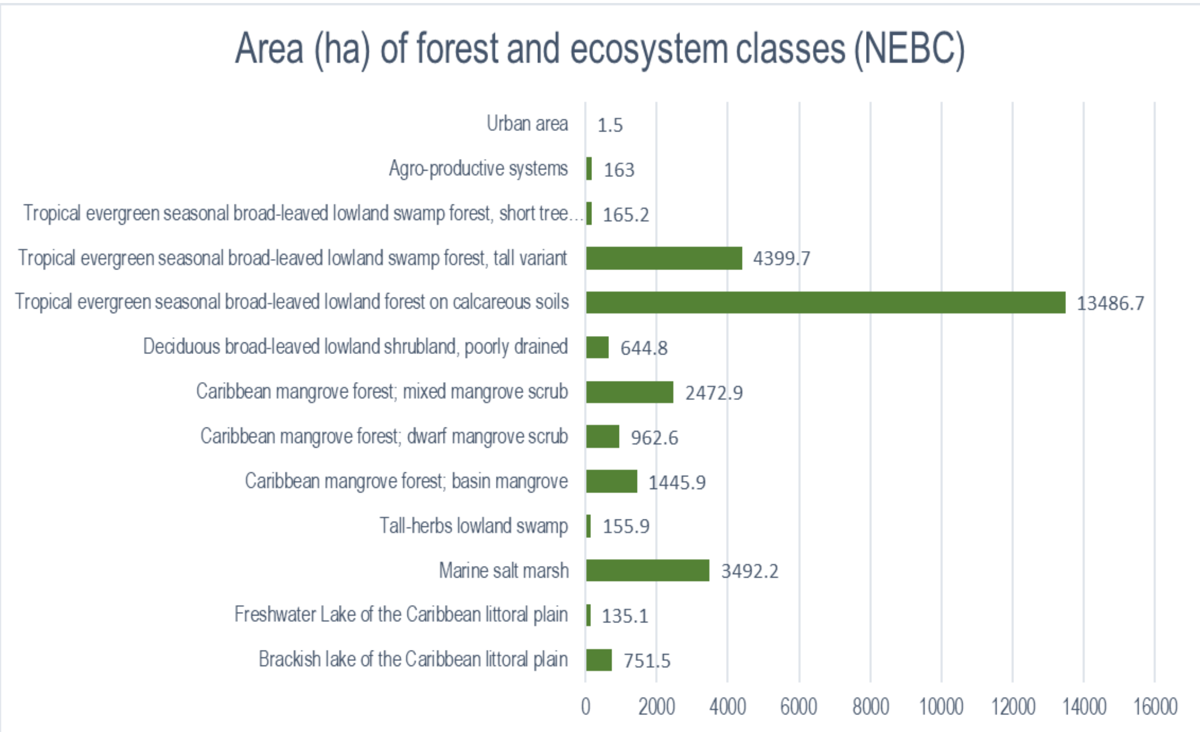


Fig. 4.3.2c *Ecosystems and forest communities of the NEBC (J. Meerman and J. Clabaugh, 2017)*



Tab. 4.3.2 *Area of NEBC ecosystem classes after 2020 (Data source: J. Meerman and J. Clabaugh, 2017)*

4.3.3 Freshwater Creek Forest Reserve

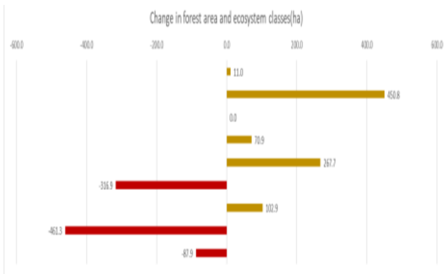
Changes in forest and protected area

***Fig. 4.3.3a** Change in forest (PFE) and protected area of the FCFR (2020)*

Older documents and more recent reports by the FAO (FRA 2000) indicate an original area for the FCFR of 29`630 hectares. Timber such as Mahogany have been extracted in the region since the 17th century. (P.L. Weaver and O.A. Sabido, 1997). Between 2010 and 2014, ca. 200 hectares of forest in FCFR were illegally cleared and temporarily used for agriculture. Thanks to pragmatic negotiations, crops have been discontinued over time. By 2020, most areas had recovered and today, they can be described as secondary young forest stands.

The boundary of the FCFR was adjusted in 2018, when the North-Eastern Biological Corridor was established (Fig 4.3.3a). The forest area under high anthropogenic pressure to the West of the reserve was declassified. An almost equivalent area of nearly 1,600 ha was acquired and attached to the North of the former reserve. As a result, the rather thin connective stripe between the former FCFR and the newly created corridor was reinforced, thus limiting a bottleneck that may have proved to be sensitive as to its management. Although these new boundaries were surveyed in the field, their official GIS layers have not yet been issued. The total area of respective ecosystem classes, as compared to those of the former reserve, have now changed with the new boundaries, as shown below.

UNESCO Ecosystem Classification	FCFR OLD (ha)	FCFR NEW (ha)	FCFR Difference (ha)
Freshwater Lake of the Caribbean littoral plain	94.8	105.8	**11.0**
Marine salt marsh	301.7	752.5	**450.8**
Caribbean mangrove forest; basin mangrove	840.2	840.2	**0.0**
Caribbean mangrove forest; mixed mangrove scrub	2036.7	2107.6	**70.9**
Deciduous broad-leaved lowland shrubland, poorly drained	359.1	626.8	**267.7**
Tropical evergreen seasonal broad-leaved lowland forest on calcareous soils	8464.8	8147.9	**-316.9**
Tropical evergreen seasonal broad-leaved lowland swamp forest, tall variant	531.2	634.1	**102.9**
Tropical evergreen seasonal broad-leaved lowland swamp forest, short tree variant	545.3	84.0	**-461.3**
Agro-productive systems	196.1	108.2	**-87.9**
Total	**13369.9**	**13407.1**	**37.2**



***Tab. 4.3.3a** Area of FCFR ecosystem classes before and after 2020 (Data source: J. Meerman and J. Clabaugh, 2017)*

The total area of the former FCFR thus remains unchanged at almost 13,400 ha. The increase in ecologically valuable freshwater lagoons and saline wetlands, such as species-rich and seasonally flooded forest communities and mangroves, means that the total forest area has decreased by 461.8 ha. Higher and more mature lowland forests have decreased by 316.9 ha, while 87.9 ha of agricultural land were part of the excised area of FCFR.

Fig. 4.3.3b archeological findings by local farmers within FCFR

The tropical rainforest communities of the FCFR are very heterogeneous and dynamic due to hurricanes. As a result of various extraction concessions over the last hundred years, the volume stock as well as the density of valuable timber tree species has been greatly reduced. The historic volumes of extracted timber and tree species abundance in past times is unfortunately hardly known. The stands can be described as degraded primary forests, intermixed with clearly secondary stands.

The Freshwater Creek area was inhabited during the Mayan culture since pre-classic times, and these communities probably already had a strong impact on forest ecosystems. Various archaeological artifacts as well as ruins have been found within FCFR (Fig. 4.3.3b, above).

Ecosystems and forest communities

Based on the national classification and mapping of ecosystems and forest communities by J Meerman (2017), the following ecosystem classes are present in the FCFR. If the maps give valuable information on a regional level, they could be refined at a more local level. A brief description of the existing ecosystem classes can be found in Appendix X.

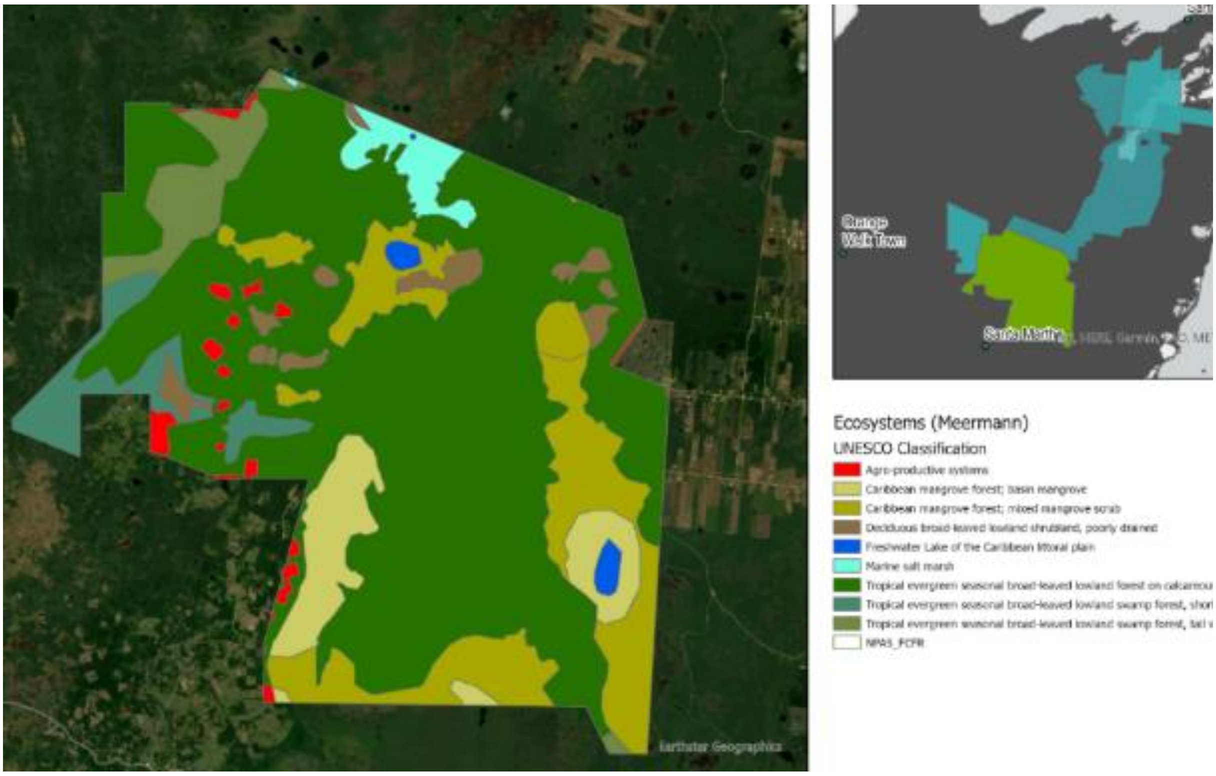
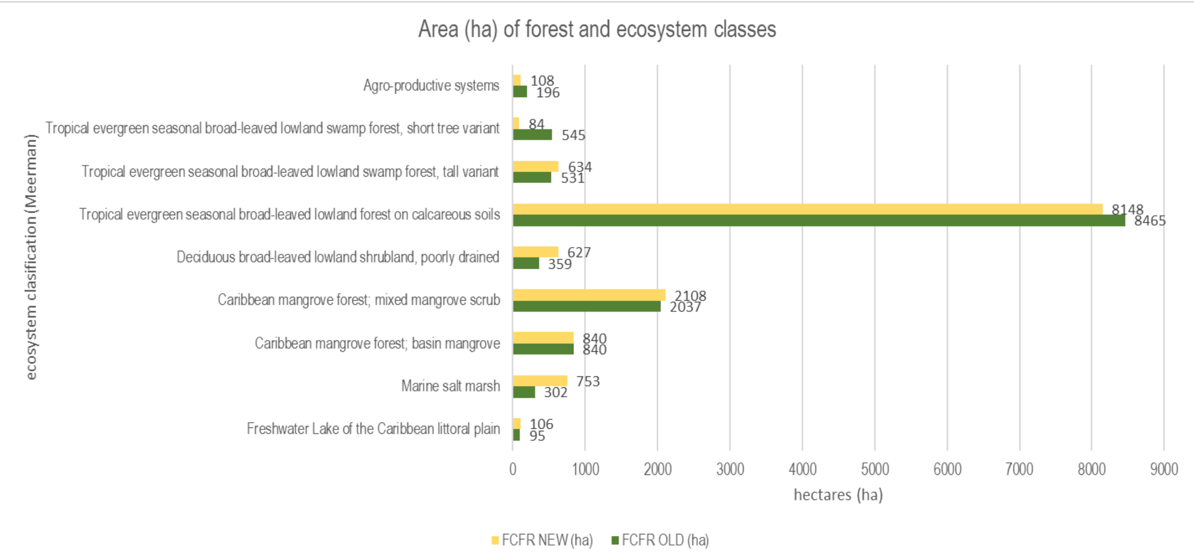


***Fig. 4.3.3c** Ecosystems and forest communities of the NEBC (J. Meerman and J. Clabaugh, 2017)*



***Tab. 4.3.3c** Area of FCFR ecosystem classes before and after 2020 (Data source: J. Meerman and J. Clabaugh, 2017)*

4.4 Forest Inventory

Fig. 4.4a *Permanent Sampling Plot Team training (FCFR 2017)*

Professional forest inventories are a requirement for sustainable forest management (SFM), silviculture as well as scientifically sound descriptions of forest ecosystems and their dynamics. Prior to 2014, forest inventory data pertaining to FCFR was hardly available or accessible. Between 2014 and 2020, an SFM inventory concept was developed by the CSFI Team in collaboration with forest experts from Belize and Switzerland, and subsequently implemented by the team during an initial pilot phase.

If forest inventory or timber harvest data from colonial times and/or pre-1981 concessions do exist, these have not been recompiled and/or digitalized. The Forest Department of Belize did however conduct several forest inventories in FCFR during the 1930s, in 1998 and 2008. Early forestry reports (Hooper, 1887; Hummel, 1921; Stevenson,1926) give estimates of the stock of commercial timber trees in different areas of the country of Belize as well as for FCFR. However, no information on the growth and mortality of trees in the natural forests was reported. Early inventories by the British were almost exclusively focused on Mahogany (*Swietenia macrophylla* King) (Tab 4.4).

Location of survey (date)	Size	Mahogany Stems / ha	Source
Freshwater Creek Reserve (1930's- 1940's)	29`630 ha	4.75	Lindo 1967
< 30 cm DBH		2.2	
30 – 60 cm DBH		3.2	
60+ cm DBH		0.3	

Tab. 4.4*. FCFR Stock Survey focused on Mahogany 1930 - 1940*

Botanical surveys have been limited to areas such as Freshwater Creek Forest Reserve and Honey Camp (Orange Walk District) southeast of the Shipstern Reserve, and to some areas in the northern part of the Corozal District - according to collecting localities cited in Bartlett (1935), Standley and Record (1936), Lundell (1940), Spellman et al. (1975) and Dwyer and Spellman (1981). The Honey Camp area, together with other areas in the Orange Walk district, have been botanically explored by Lundell, Meyer & Karling in the 1930s. (Bijleveld, 1997)

4.4.1 National forest Inventory Plots

Bird gives the following account on permanent sample plots in Belize**:** "*Very little research has been carried out on the dynamic processes of tree growth and mortality in the natural broadleaf forests of Belize. The lack of such information constrains forest management. To address this deficiency, the Forest Planning and Management Project established thirty permanent sample plots across a range of forest types throughout Belize (1992-1998). Two of this Plots was established 1993 inside FCFR. Each plot is square and is 1 ha in size (100 m x 100 m). All trees with a stem diameter at breast height (dbh) [1.3 m above ground level] equal to or greater than 10 cm were measured. To assess growth and mortality of saplings, all trees greater than 1 cm dbh were measured within the central 20 m x 20 m quadrat. The two plots within FCFR have very high tree densities, in an area which appears to be recovering from recent catastrophic wind damage".* (N.M. Bird ,1992-1998, FD, NRI, University of Greenwich, Sustaining the Yield, improved timber harvesting practices in Belize).

Focusing on the target tree species Mahogany (*Swietenia macrophylla*), it is interesting to note that in Plot 9 (15 S.m. / ha) and in Plot 10 (12 S.m. / ha) were inventoried. They were, however, of small diameter classes (10 - 39 cm dbh). In 1992, at least one Mahogany was present in Plot 9 in the 60 - 69 cm / BHD diameter class. Whether the plot location was statistically random or placed in a stand with high Mahogany density is unfortunately not known. The complete table of 1993 inventory data can be found in Appendix X.

Plot ID	Number of tree species	10-19 cm	20-29 cm	30-39 cm	40-49 cm	50-59 cm	60-69 cm	70-79 cm	80-89 cm	90-99 cm	> 100 cm	Total
Plot 9	51	645	219	56	18	11	2	1	0	1	1	954
Plot 10	53	660	233	60	16	0	0	2	1	0	0	972

Tab. 4.4.1 *Summary of FCFR permanent plots, established 1993 (N. Bird)*

Dr. Percival Cho, former forest officer and CEO of MAEDDSF has continued the project initiated by Bird under FD leadership, resurveying existing plots and installing additional plots throughout the country. In FCFR, three additional plots were created in collaboration with the CSFI team. These valuable data provide accurate topical information on stand structure in FCFR, over on a longer period of time. The data, however, are not included in this report.

Plot 9, established in 1993, was resurveyed in 2015 by the FD and CSFI team. Unfortunately, the stand was harvested during a logging concession between 2005 and 2012 and thus the data are affected. Silas Hobi, a forest engineer carrying out his Swiss civil service for the benefit of CSFI, analyzed the data as shown below and the detailed report is found in the references

Table 8: Volume estimation using different formulas. Vincr93-15 is the measured volume increase between 1993 and 2015. Vincr yr-1 is the annual volume increase and V25cc is the expected volume increase in a 25 years cutting cycle.

m^3ha^{-1}

Shape	Abbreviation	Formula	Vincr93-15	Vincr yr^{-1}	V25cc	Stock 15
Rough Estimate	Vdenzin	V=DBH^2*10	100.3	4.6	114.0	348.4
Cylinder	V10m	V=B*10m	78.8	3.6	89.5	273.6
Cylinder	Vhm	V=B*hmeasured	80.3	3.6	91.2	277.2
Cone	Vf0.33	V=B*hmeasured*0.33	26.5	1.2	30.1	91.5
Cone / Cylinder	Vf0.42	V=B*hmeasured*0.42	33.7	1.5	38.3	116.4
Cone / Cylinder	Vf0.5	V=B*hmeasured*0.5	40.1	1.8	45.6	138.6

Table 9: Diameter and volume increase of timber species present on the PP

		Increase					Stock
	n	mean DBH	min DBH	max DBH	Vf0.42	Vf0.42 25CC	StockVf0.42
		cmyr^{-1}	cmyr^{-1}	cmyr^{-1}	m^{3}yr^{-1}	m^{3}25yr^{-1}	m^3
Total	**74**	**0.24**	**0.005**	**0.77**	**0.31**	**7.9**	**20.6**
Bastard Rosewood	1	0.05	0.05	0.05	0	0	0.2
Black Poisonwood	20	0.29	0.02	0.76	0.09	2.4	5.9
Cabbage Bark (yellow)	9	0.24	0.06	0.39	0.05	1.3	3.2
Hobillo	6	0.15	0.02	0.37	0.02	0.5	1.9
*Mahogany	4	0.27	0.07	0.65	0.03	0.7	1.3
Redwood	13	0.14	0.005	0.3	0.02	0.6	2.4
Red Sillion	21	0.28	0.07	0.55	0.09	2.4	5.7
**White gumbolimbo	21	0.22	0.01	0.57	0.11	2.7	8.2

*high value species

**low value species (not included in total)

From his analyses, Hobi concluded: “*At present only little information about increment of growth exists. Although, the re-measurement of a PP allows a rough estimate, it may not represent the whole area. Knowledge about diameter increase of each tree species with economic interest has to be improved. Long-term research on diameter increase under varying growth conditions (light, soil, nutrients, moisture etc.) is highly recommended.*

The high range between minimum and maximum diameter increase indicates that light probably plays an important role in accelerating growth increments. Within the next 25 years, it is recommended to increase the share of timber species compared to non-timber species applying different silvicultural techniques”.

4.4.2 FCFR Inventory Plots FD (2008)

The Forest Department conducted an operational inventory of FCFR in 2008 under the direction of Dr. Percival Cho. There were 36 plots inventoried across the entire FCFR. These data could not be analyzed within the scope of this report. Nevertheless, the inventory was conducted prior to the last logging concession and shows that higher diameter classes then present fail to appear in the inventories carried out in 2014 ND onwards. In 2008, 73 Mahoganies were recorded, but only two of those had a DBH greater than 60 cm (61.4 cm and 66.2 cm respectively).

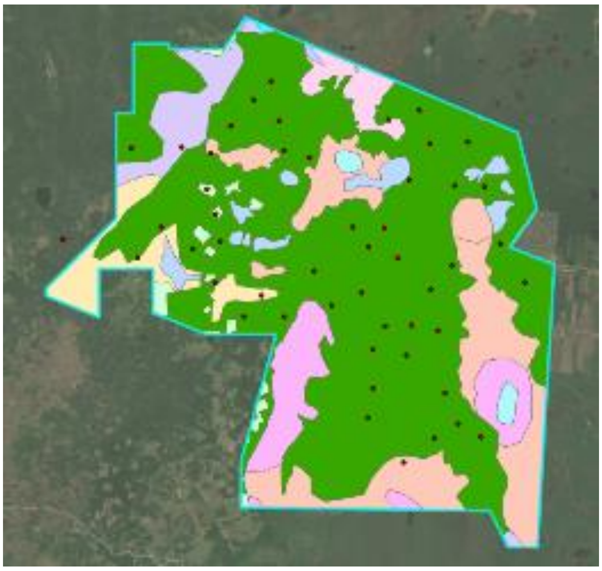


Fig. 4.4.2 *Distribution of inventory plots in FCFR. Inventory data is available for 36 of the 49 plots. The inventory design is not known.*

4.4.3 Shipstern forest and botanical Survey Plots (1998)

The transect in Shipstern is 2625m long, with a total of 21 plots established every 125m in 1998. The center of each plot is marked in the field, 30 m away from the survey line on its eastern side. Each plot measures 10m x 10m (i.e. 100 m^2), and is divided in four 5m x 5m subplots to facilitate mapping and data collecting. The vegetation of each plot was mapped both horizontally and vertically. The following data was gathered:

- position of the trunk
- position of the crown, determined by two perpendicular diameters. The crown shape was reproduced as precisely as possible.
- trunk diameter at breast height, measured with a sliding ruler for trees less than DBH 13cm. The diameter was obtained by calculation based on the circumference in the case of trees with a DBH above 13cm. NB: for analyses' purposes, diameters recorded as being less than 1 cm were given the standard value of 1. Accordingly, standard basal area values given are 0.79 cm2.
- height: the vegetation being moderately low in most plots, a 10m graduated pole was used to measure height. Height is understood here as being the distance separating the base of the tree to the top of its crown. Whenever necessary, the height of the first trunk fork was measured.

The analysis and results of the inventory are published in "The Vegetation of Shipstern Nature Reserve (C. Bijleveld, 1998)".

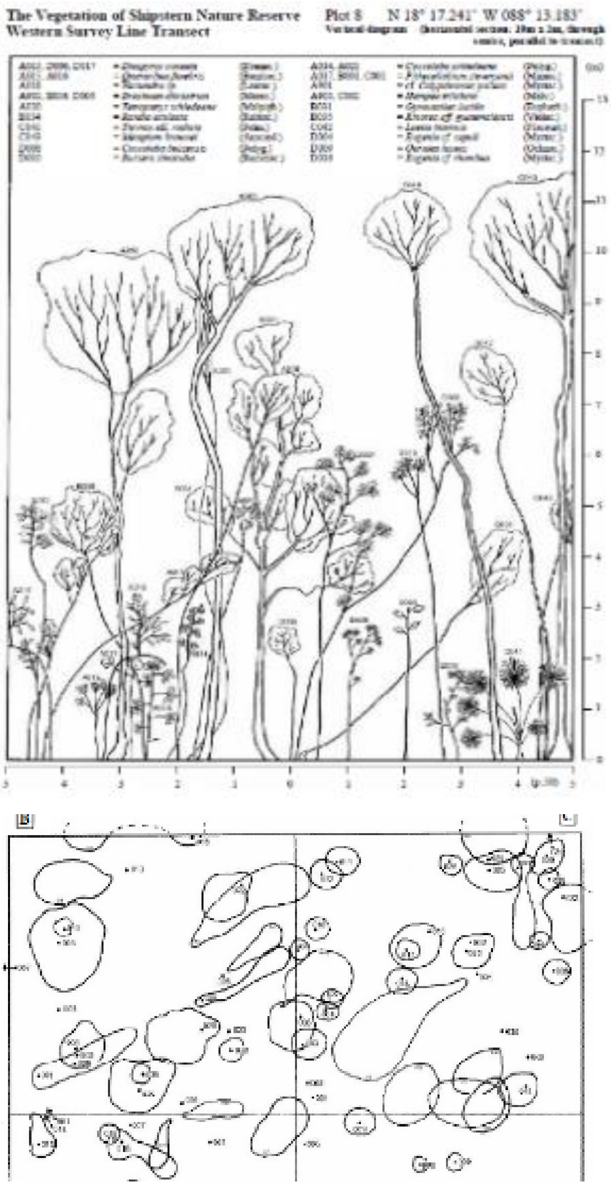


Figure 4.4.2 *transects and horizontal mapping of plot 8 in medium-sized semi evergreen Yucatan forest, near the western border of Shipstern (as in Bijleveld, 1998)*

4.4.4 CSFI Forest Inventory

Fig. 4.4.4a *Forest Inventory Workshop CSFI Team and Dr. Ch. Fischer, Shipstern 2018*

Since the project's inception in 2014, the CSFI team has been analyzing and describing forest stands in FCFR forest stands by use of various forest inventory methods focused around sustainable forest management. A simple spectral analysis based on Rapid Eye satellite data was carried out, which was subsequently verified in the field with GPS recordings. Larger isolated trees discovered during field missions were carefully inventoried. In addition, permanent sampling plots were established and stock surveys conducted. The inventory methods and their results are described further below.

In collaboration with and based on the expertise of SFM specialist in Belize (FD, Dr. Percival Cho) and Switzerland (WSL U-B. Brändli, Dr. CH. Fischer and the NFI Team, HAFL, Prof. J. Blaser, O. Gardi), a concept of permanent forest inventory plots, based on the initial inventory pilot phase 2014-2018, was developed for the whole NEBC and at first implemented within FCFR (WSL meeting note 2016. Appendix). In the process, the CSFI team was trained in forest inventory and botany by Forest Department staff and forest experts from Switzerland (H. Martinez, P. Walther, S. Hobi, T. Schmid).

Dr. Christoph Fischer, deputy head of the Swiss national forest inventory visited the CSFI team and the inventory program on site during one week in 2018. Various workshops were held with the CEO and forest officers of the FD, as well as with the CSFI team.

The main topics of the multi-partner workshop pertained to data quality, data management and the statistical significance of field surveys (Fig 4.4.4 a-c).

Fig. 4.4.4b *Discussion of the statistical significance of edge trees .*

Fig. 4.4.4c *Discussion about the statistical evaluation of additionally recorded attributes*

Chronology of CSFI Forest Inventory Program

Year	Measures	Documents (appendix)
2014	• Spatial analyses of FCFR based on RapidEye spatial data (Dr. P. Cho / P. Walther) • Trial of 25 PSP according to Swiss national forest inventory (NFI) • 9 hectares Stock survey	• FCFR Annual Report 2014 (P.Walther / CSFI Team)
2015	• 53 hectares Stock Survey • Re-measurement national plot (1 hectare)	• SFM FCFR Background Information (S.Hobi / CSFI Team)
2016	• Unknown hectares of Stock survey (10-30 ha?)	• Concept for forest inventories, scientific report (P. Walther, HAFL / LFI Team) • Field notes FCFR forest inventories, 16.12.2016, WSL Birmenstorf (U-B. Brändli & LFI Team, P.Walther) • Field report (Daniela, R. Locher / CSFI Team)
2017	• Installation of 18 PSP (Pilot phase) • Re-measurement of 13 PSP • 2 months Botanical training from Mr. Henry Piedra Martinez, a botanist from the Papiliorama including of species samples • Trial of Bird monitoring (point count) on Forest inventory Plots (L. Sorrenti)	• Evaluation report of the first year of Permanent Sampling point collection at CSFI (T. Schmid / CSFI Team) • 2 months Botanical training from Mr. Henry Piedra Martinez, botanist at Papiliorama Foundation
2018	• Field Visit from Dr. CH. Fischer (NFI / WSL) including CSFI Team workshop and field training • Continuation PSP pilot phase • Transect Inventory by Heron Moreno Jr.	• Permanent Forest Inventory Field Manual (T. Schmid, P. Walther / CSFI Team) • Evaluation report of the Permanent Sampling point collection at CSFI in 2017/18 and perspectives of a CSFI Forest inventory system (T. Schmid / CSFI Team)
2019 and 2020	• Installation of 32 PSP • 2 months botanical training from Mr. Henry Piedra Martinez, botanist.	• Excel files from PSP (CSFI Team) • (C510) PSP Evaluation Report 2017 – 2020 (T. Schmid, P. Walther, 2020)

4.4.5 Remote sensing and spectral analysis

Fig. 4.4.5 *Spectral analyzing of FCFR HCVs based on ARCGIS applications and RapidEye data.*

Initial baseline maps of FCFR were based on remote sensing and spectral analysis of RapidEye satellite data from 2011 with a resolution of 5 * 5 m / pixel. These data were supplemented with current Sentinel 2 data in order, for example to, detect the illegal agricultural clearings in FCFR. As is usual with satellite data, cloud cover can be problematic and therefore, datasets usually have to be combined. All data were verified in the field with GPS samples.

A pilot project proposed by Mark Günter, GIS and drone specialist at HAFL, to map stands at FCFR using drones could unfortunately not be carried out. Also, LIDAR sensors and high resolution and georeferenced RGB data could be of value for detailed mapping. New data sources (satellite and drone sensors) and remote sensing have made tremendous progress in recent years and should be considered for any future work on forest mapping.

4.4.6 CSFI Permanent Sampling Plots

Fig. 4.4.6a *Instruction on data collection using GPS and Open Foris Field App (FCFR Team 2017)*

Chapter 4.4.6 and the PSP data analysis were developed and written by Tobias Schmid, Forest Engineer. His evaluation report in full can be found under in the references

4.4.6.1 Research baselines

In 2018, the Corozal Sustainable Future Initiative (CSFI) aimed at establishing a forest inventory, in order to give answers to the following baseline questions with regard to the area:

- What is the current state and structure of the forests? (species composition, diameter classes, forest structure, age class structure, basal areas, etc.)
- What is the current distribution of the various forest types within the North-eastern Biological Corridor?
- Which changes in the forest composition can be observed over time and how are they influenced by sustainable forest management practices or climate change (DBH growth rate, mortality, species composition, etc.)?
- Can a recovery of the forest composition (DBH distribution and species composition) be observed through sustainable forest management and protection?

4.4.6.2 Plot Design

Each plot consisted of two circles, an inner circle of 12.62 (500 m^2) m radius and an outer circle with 28.22 m radius (2`500 m^2) (Fig. 4.4.6b). During the data collection phase from 2017 – 2018 the DBH threshold for the inner circle was at 6 cm and for the outer circle at 40 cm. For the period from 2019 – 2020 the threshold for the outer circle was lowered to 25 cm to obtain a larger sample size per plot, as the threshold of 40 cm proved to deliver only very low sample sizes.

The DBH was measured at 1.30 m with a DBH measuring tape and marked with a chisel. The tree was marked with a numbered tag. If a reproducible measurement at 1.30 m was not possible a POM (Point of Measurement) was defined, based on the description in the CSFI Forest Inventory field manual.

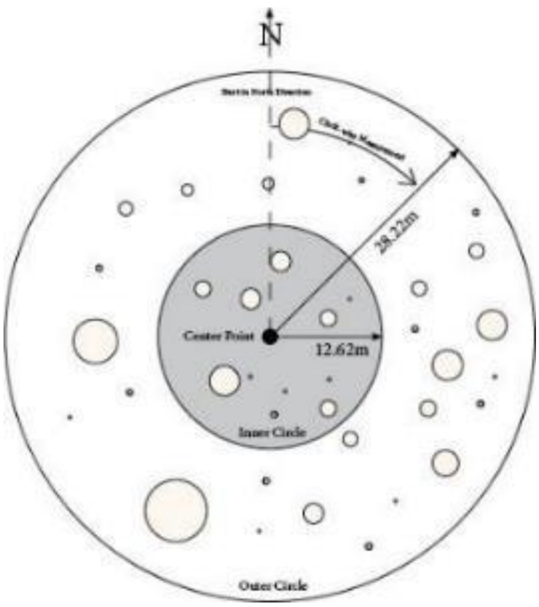


Fig. 4.4.6b Plot design for the CSFI forest inventory plots. Following graphics of the PSP Project (chapter 4.4.6) are developed by T. Schmid in collaboration with the FCFR Team.

4.4.6.3 Grid Design

The inventory area includes all lands within the North-eastern Biological Corridor (NEBC) as well as Shipstern (SCMA). A pre-classification of potential forest inventory plots was conducted based on the ecosystem classification by Meerman et al. 2015 and the most up-to-date aerial Google Earth imagery of 2017. (Fig 4.4.6c).

The classes "Lowland broad-leaved moist forest", "Lowland broad-leaved moist scrub forest" as well as "Lowland dry forest" were chosen in priority as potential sites for the establishment of forest plots. The category "Mangrove and Littoral Forest" was considered, but not in highest priority, whereas the categories "Wetland"," Water" and "Agriculture" were discarded. A shown on the vegetation map, most forested areas are located in Honey Camp – Freshwater Creek (Figure 5). In comparison, only little lowland broadleaved forest is found in Shipstern CMA, whereas the regionally rare broad-leaved dry forest can only be found in Shipstern.

A "Forest/Non-Forest Decision Tree" was developed to help field team decide whether a particular plot was to be retained or)discarded (Appw dix 13.3.1

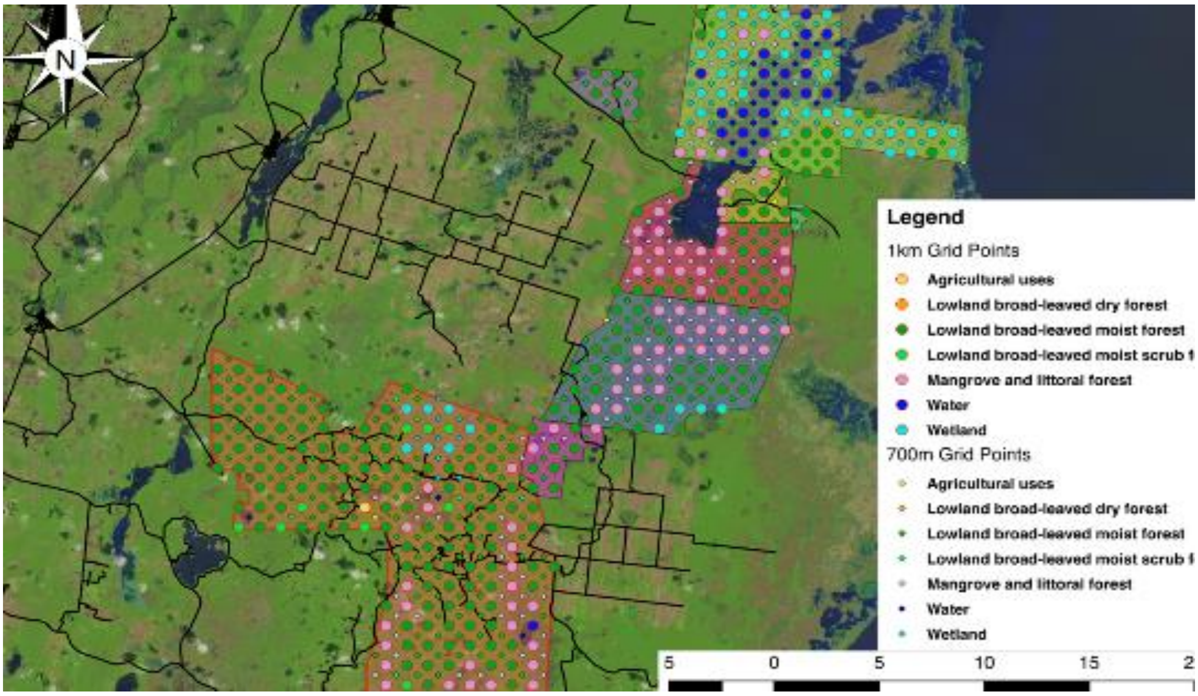


Fig. 4.4.6c *Proposal for a flexible Grid Design based on the idea of the Swiss Forest inventory grid. The larger points resemble a 1000 m grid, on which plots will be sampled for the next 2.5 years. If the data collection is still on track, the 700 m grid points (smaller and diamond shaped) will be sampled (T. Schmid, 2018).*

4.4.6.4 Inventory Coordinate System

Equally, a local coordinate system was designed to ensure a unique ID for each sampling plot. The purpose of the coordinate system is to serve as a backup for collected data, in order to alleviate the risk of data confusion during manual collection on paper. Furthermore, the aim was to be able to use the same system for flora, fauna or bird monitoring, or any other field studies using locations.

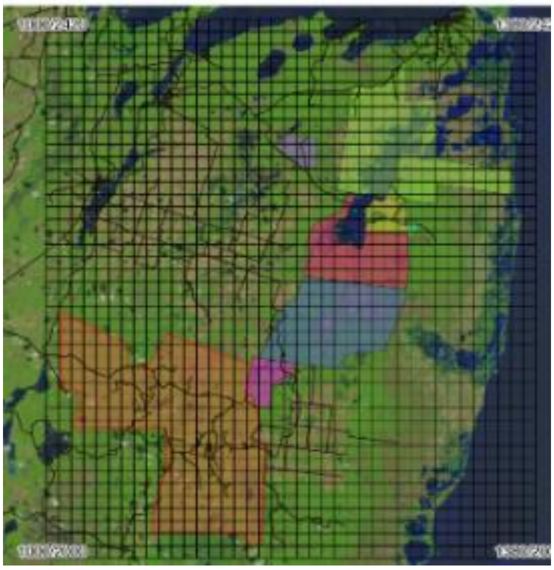


Fig. 4.4.6d *The grid design for the North-eastern Biological Corridor and Shipstern system. The coordinates have received a unique number on each axis (T. Schmid, 2018).*

4.4.6.5 Grid density and sampling pattern

Grid densities of 500m, 700m and 1000m were compared (Tab. 4.4.6a). The management of CSFI estimating that on average two plots per week could be sampled, one could sample approximately 100 plots a year. Based on this estimate, the 700m grid was selected, since it required the sampling of approximately 84 plots per annum.

Aware that the current phase was only a pilot one, the design was structured in such a way that adjustments were in future possible, with minimized risk of data loss. As such, it was decided to sample first all points on the coarser 1000m grid, and later on only the ones on the 700m grid (Fig. 4.4.6e).

The current length of the measurement cycle was set at five years, whereas the exact design of the grid would depend on the results of the calibration data as well as propositions by the WSL and other external experts.

The sampling plots were blocked into groups of five, thus allowing for a homogeneous spread of sampling points throughout the protected areas. Furthermore, this system would ensure that field personnel was present in all parts of the protected area throughout the year.

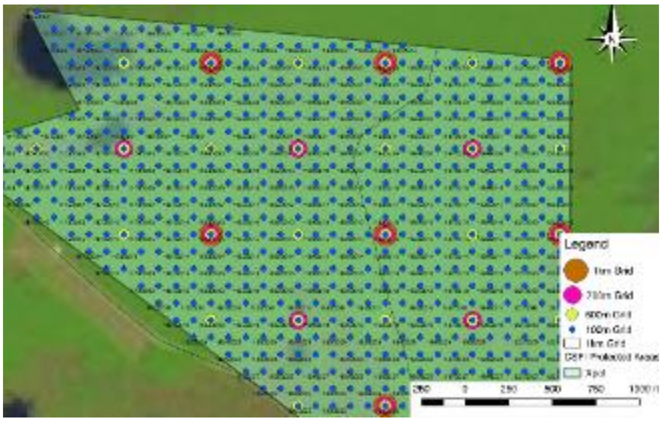


Fig. 4.4.6e *Different levels of grid resolutions that can be used with a systematic grid for different studies, depending on resources available and research topics. The concept reflects the idea of the Swiss forest inventory grid, but can be adapted at a later stage (T. Schmid, 2018).*

Landcover Type	**1000m Grid**	**700 m Grid**	**500 m Grid**
Agriculture	1	4	7
Lowland Dry Forest	2	3	10
Lowland broad-leaved moist Forest	210	397	793
Lowland broad-leaved moist scrub Forest	10	17	33
Mangrove and littoral forest	79	164	332
Water	21	43	87
Wetland	46	91	183
Probability of correct classification as forest			
Very probable	211	417	836
Uncertain	79	164	332
Most likely not	79	138	277
Expected Range of Inventory plots	**192 - 252**	**392 - 452**	**806 - 866**

Tab. 4.4.6a *A comparison of the number of points within the protected areas of CSFI that would have to be measured under different grid resolutions. The Vegetation map by Meerman et. al 2015 serves as a rough classifier for the different vegetation types and the probability that those will fall within the forest inventory (T. Schmid, 2018).*

***Fig.* 4.4.6e/f** PSP Team Training 2017 (left) and 2014 (right)

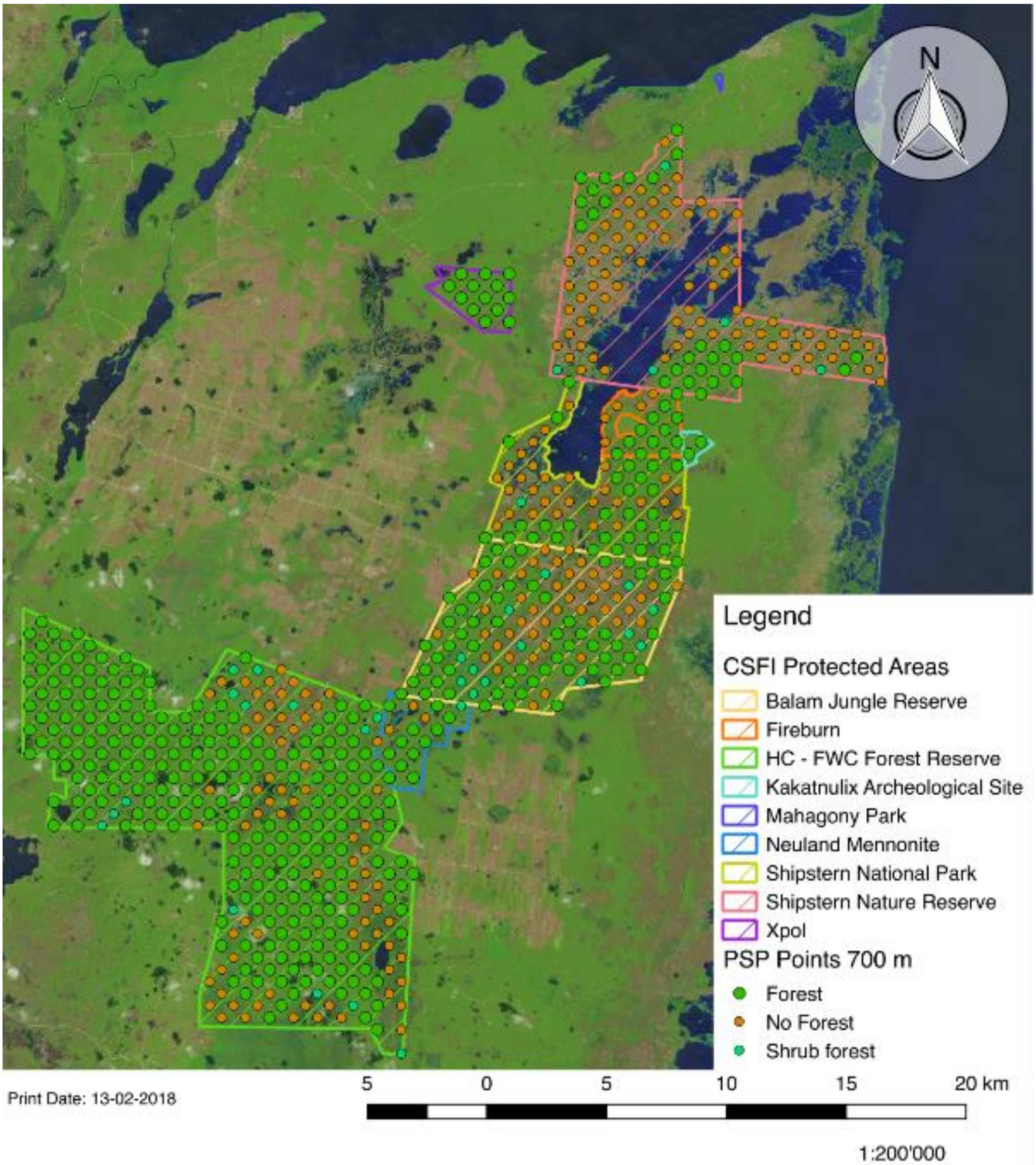


Fig. 4.4.6g *Different categories based on the pre-classification based on the vegetation map of Meerman et al. 2015 and Google Earth images(T. Schmid, 2018) .*

4.4.6.6 Data collection

Phase I: Beginning of 2017 to mid-June 2017

During the first sampling phase the collection methodology, tree species identification skills and the OpenForis Collect app were tested and the forest inventory team was familiarized with data collection procedures. The sites of the plots were distributed throughout Freshwater Creek Forest Reserve and grouped in series of five from west to east. The distance between each plot centre was 100 m. Prior to the start of the field work ten blocks of 5 plots were predefined by computer to ensure randomness (Figure 10).

An exception were the 13 plots which were established in 2014. These were re-measured to estimate sampling accuracy and to gather experience with data collection, which included a proper training on how to measure the DBH of a tree. During phase I, 18 new sampling plots were established and measured.

Phase II: July 2017 – January 2018

During the summer of 2017, two CSFI members received proper tree identification training from Mr. Henry Piedra Martinez, botanist at the Papiliorama Foundation in Switzerland. This training improved existing botanical knowledge, and allowed for more accuracy in tree identification, thus significantly diminishing error rates.

Changes in personnel during the summer 2017 asked for adjustments, and eight plots from the first phase were re-measured as part of an internal training. The improved botanical knowledge helped refine data. Later on, nine new plots were measured (Fig. 4.4.6i).

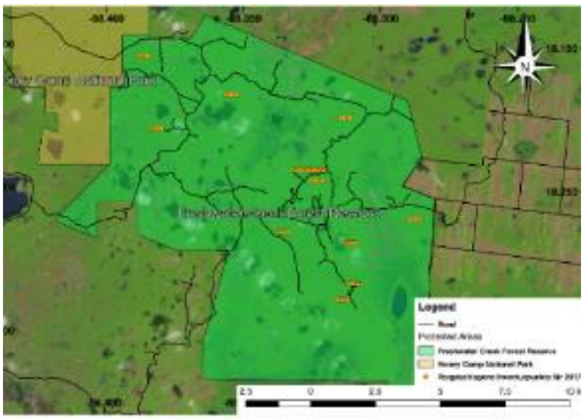


***Fig.* 4.4.6h** *Proposed forest inventory plot setup for 2017. Not all of the sampling points were measured, as the idea was that blocking plots would allow a higher sample size with less effort.*

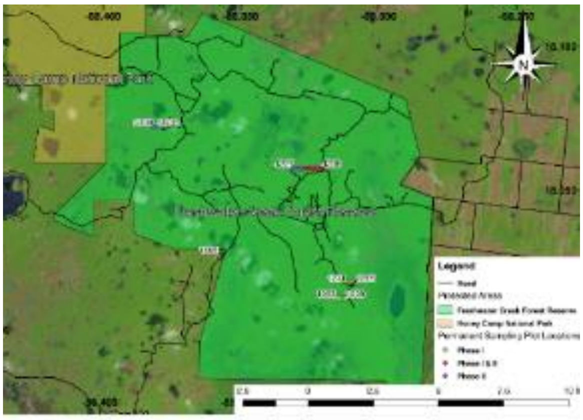


***Fig.* 4.4.6i** *Locations of the forest inventory pilot plots 2017 collected in Freshwater Creek Forest Reserve*

Phase III: 2019 – 2020

Prior to the field seasons of 2019 – 2020, forest inventory design had been established and the CSFI forestry team was well familiarized with its protocols. During the data collection period from 2019 to 2020, 36 plots were sampled. Of those four plots were classified as non-forest and 32 plots were classified as forest. The data was collected by hand and later on digitalized to an Excel spreadsheet.

Fig. 4.4.6.j *CSFI Ranger A. Abner and R. Locher (Agroforestry Expert from Switzerland) with the largest remaining tree (Guanacaste) found so far within FCFR*

Fig. 4.4.6.k *Former CSFI Head ranger Lester Delgado with a nice Mahogany discovered in one of the 2014 PSP*

4.4.6.7 PSP results

2017 - 2020

4641 trees were sampled in 59 sampling plots (Fig, 4.4.6l). The mean DBH of the inner circle was 15 cm and for the outer circle 50 cm (40 cm DBH threshold). Stem number in the inner circle is 1157 trees/ha and in the outer circle 25 trees/ha. The most common tree in the inner circle was Black Poisonwood (*Metopium brownei)* and in the outer circle Warree wood (*Caesalpinia gaumeri*) (Tab. 4.4.6.b).

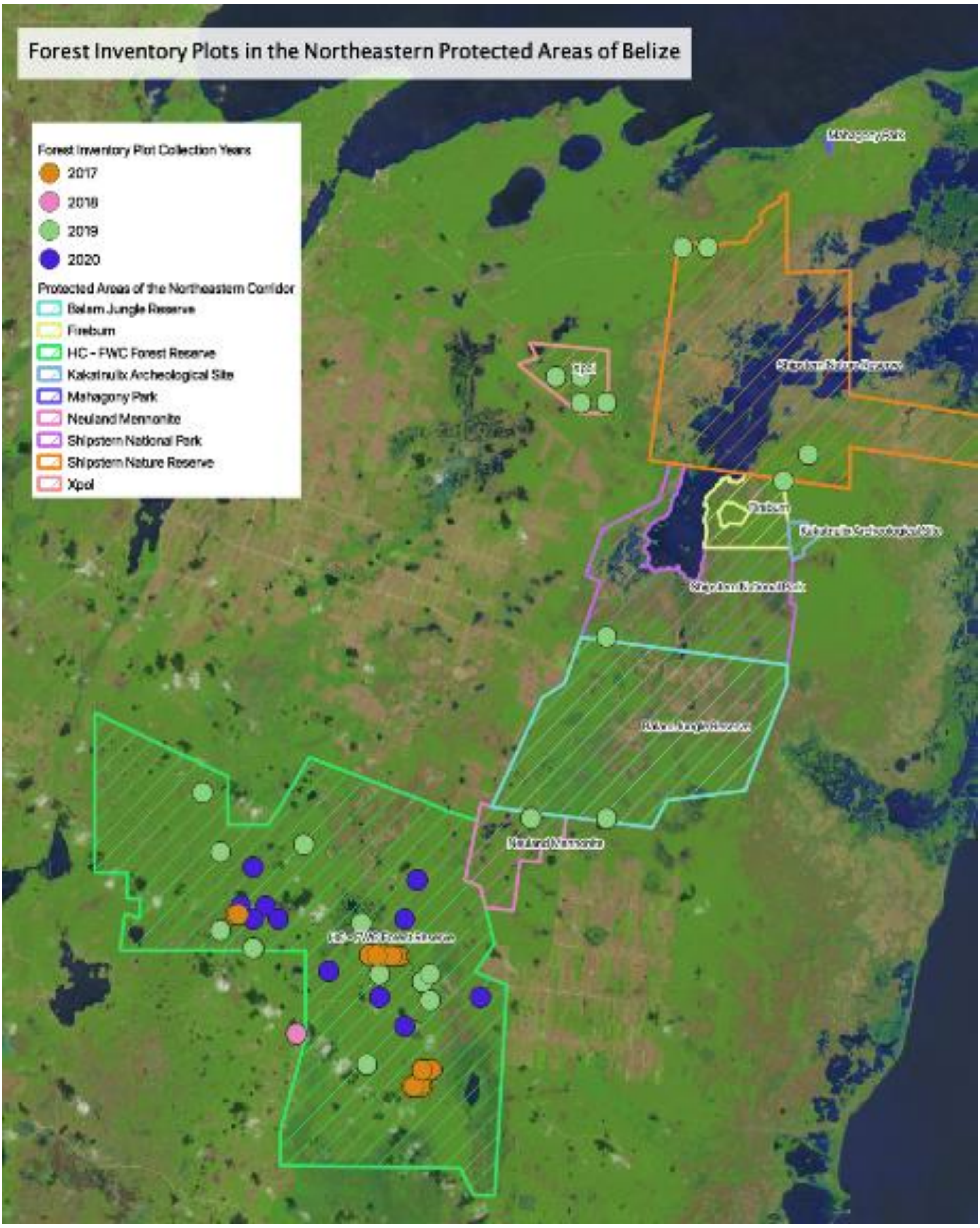
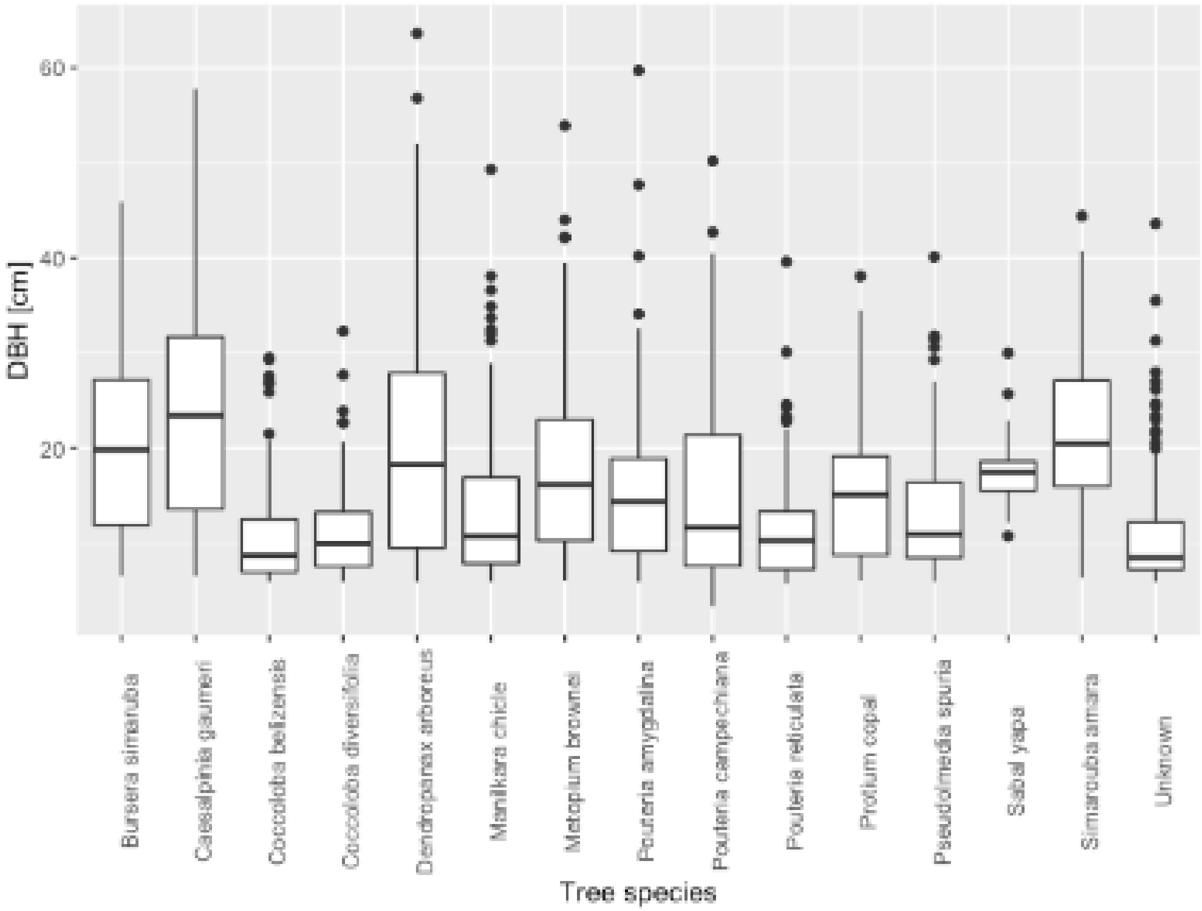


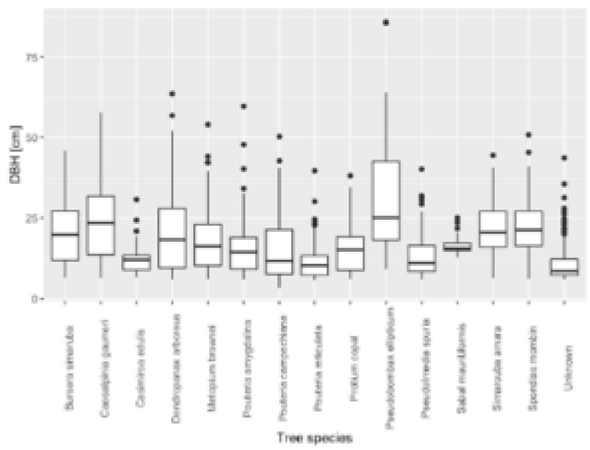
Fig. 4.4.6l *Forest inventory plot locations from 2017 - 2020 in the different parts of the North-eastern Biological Corridor. The clustering of points in the early stages (2017) is due to a different pilot sampling design, which was changed after the pilot phase ended, in 2019 (T. Schmid, 2018).*



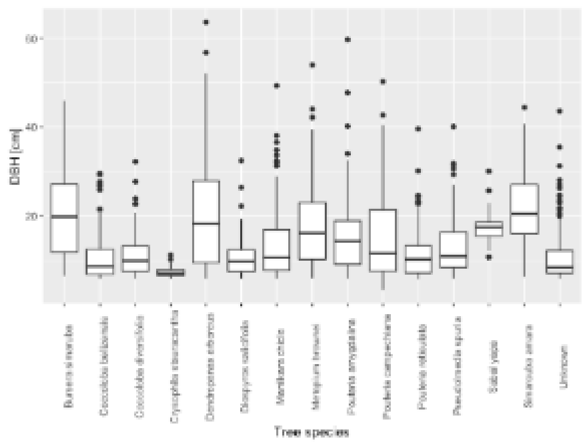
Tab. 4.4.6.b *DBH distribution of the 15 most common species in the sampling period from 2017 – 2020 (T. Schmid, 2020).*

2017 - 2018

1572 trees were sampled in 27 forest inventory plots. The mean DBH of the inner circle is 16.7 cm and for the outer circle 50 cm (40 cm DBH threshold). Stem number in the inner circle is 955 trees/ha and in the outer circle 28 trees/ha. The most common tree in the inner circle was Sapotillio (*Pouteria reticulata)* and in the outer circle Mapola (*Pseudobombax ellipticum) (*Tab. 4.4.6.c)



Tab. 4.4.6.c *DBH distribution of the 15 most common tree species in the sampling period from 2017 – 2018 (T. Schmid, 2020).*



Tab. 4.4.6.d *DBH distribution of the 15 most common species sampled from 2019 – 2020 (T. Schmid, 2020).*

2019 – 2020

2641 trees were sampled in 32 Forest inventory plots. The mean DBH of the inner circle is 14 cm and for the outer circle 35 cm (25 cm DBH threshold). Stem number in the inner circle is 1328 trees/ha and in the outer circle 93 trees/ha. The most common tree in the inner and the outer circle is Black Poisonwood (*Metopium brownei) (*Tab. 4.4.6.d*).*

***Tab. 4.4.6.e** The results of the FOREST INVENTORY PLOT data from 2017 – 2020 (T. Schmid, 2020).*

Sampling period	**2017-2020**	**2017-2018**	**2019-2020**
Number of species identified	124	85	111
Sample size	4213	1572	2641
Number of unidentified trees	200	107	93
Mean DBH (cm) - Inner Circle	15.06	16.77	14.02
Mean DBH (cm) - Outer Circle	50.76	49.75	35.39
Mean basal area (m2/ha) - Inner Circle	29.81	29.36	28.59
Mean basal area (m2/ha) - Outer Circle	5.46	5.77	10.12
Stem number per hectare (Mean) - Inner Circle DBH threshold at 6 cm	1157	955	1328
Stem number per hectare (Mean) - Outer Circle	25.4 (Threshold DBH at 40cm)	28.3 (Threshold DBH at 40cm)	93 (Threshold DBH at 25cm)
Largest Tree (DBH, cm)	Ficus spp. 128.2	Ficus spp. 128.2	Manilkara chicle 123.4
Most common tree (#) - Inner Circle	Metopium brownei - Black Poisonwood (248)	Pouteria reticulata – Sapotillo (129)	Metopium brownei - Black Poisonwood (184)
Most common tree (#) - Outer Circle	Caesalpinia gaumeri - Warree Wood (51)	Pseudobombax ellipticum - Mapola (28)	Metopium brownei - Black Poisonwood (143)
Dominance- Inner Circle (relative)	Metopium brownei 8.86%	Caesalpinia gaumeri 8.91%	Metopium brownei 12.27%
	Pseudobombax ellipticum 6.17%	Dendropanax arboreus 7.89%	Vitex gaumeri 6.13%
	Caesalpinia gaumeri 5.98%	Pseudobombax ellipticum 7.73%	Bursera simaruba 5.14%
	Bursera simaruba 5.47%	Bursera simaruba 5.85%	Pseudobombax ellipticum 4.82%
	Dendropanax arboreus 5.46%	Spondias mombin 5.51%	Simarouba amara 4.46%
Dominance - Outer Circle (relative)	Caesalpinia gaumeri 15.33%	Pseudobombax ellipticum 17.61%	Metopium brownei 15.10%
	Pseudobombax ellipticum 14.56%	Caesalpinia gaumeri 13.29%	Caesalpinia gaumeri 12.10%
	Manilkara chicle 8.74%	Dendropanax arboreus 11.69%	Manilkara chicle 8.22%
	Dendropanax arboreus 8.27%	Pouteria amygdalina 9.50%	Bursera simaruba 7.80%
	Vitex gaumeri 7.50%	Bursera simaruba 8.38%	Pseudobombax ellipticum 7.10%
Frequency - Inner Circle (Grouped)	Metopium brownei 60-80%	Pouteria reticulata 60-80%	Metopium brownei 60-80%
	Bursera simaruba 60-80%	Bursera simaruba 60-80%	Coccoloba diversifolia 60-80%
	Simarouba amara 60-80%	Caesalpinia gaumeri 60-80%	Bursera simaruba 60-80%
	Pouteria reticulata 60-80%	Metopium brownei 60-80%	Manilkara chicle 60-80%
	Caesalpinia gaumeri 60-80%	Simarouba amara 60-80%	Sabal yapa 60-80%
Frequency - Outer Circle (Grouped)	Caesalpinia gaumeri 40-60%	Caesalpinia gaumeri 40-60%	Metopium brownei 60-80%
	Pseudobombax ellipticum 20-40%	Dendropanax arboreus 40-60%	Bursera simaruba 60-80%
	Bursera simaruba 20-40%	Pseudobombax ellipticum 40-60%	Caesalpinia gaumeri 40-60%
	Dendropanax arboreus 20-40%	Bursera simaruba 40-60%	Manilkara chicle 40-60%
	Vitex gaumeri 20-40%	Pouteria amygdalina 20-40%	Simarouba amara 40-60%
Volume (All species)			
Volume - Inner Circle (m^3/ha) F-Factor 0.33-0.42	458 - 583	465 - 591	453 - 576

Volume - Outer Circle (m^3/ha) F-Factor 0.33-0.42	34 - 44	37- 47	67 - 85

Mahoganies

In total 38 Mahoganies (*Swietiana macrophylla*) were recorded ranging from 7 to 52.7 cm DBH. The mean density calculated is 2.5 trees per hectare(T. Schmid, 2018) .

Sample size	37	18	19
DBH range (cm)	7-52.70	7-46.5	7-52.70
Mean DBH (cm)	26.57	27.34	25.81
Mean Mahoganies/ha	2.5	2.8	2.4

4.4.6.8 Discussion

Data collection and implementation of the inventory design

From 2019 to 2020, 36 forest inventory plots were sampled by the forest inventory team. According to the original design, 84 plots should be sampled each year, in order to sample all plots within five years. Based on the current trajectory of an average of 18 plots per year, a reduction of plot density to the 1000 m grid will not suffice to get the inventory team back on track (39 plots per year). In addition to the low numbers of sampled plots, the collection pattern was not carried out exactly as was planned, i.e. in accordance with the blocking proposed in the inventory design. Therefore, some plots do not fall into the 1000 m grid and will statistically not be useable, even if the grid was to be changed to the 1000 m grid.

Input errors

Raw data was collected by hand and later on inserted into separate Excel-sheets. During this process different types of errors have been discovered in plot numbers, coordinates, DBH and species name.

Uncertainty remains as to taxonomic accuracy. As a matter of fact, the two sampling periods 2017-2018 and 2019-2020 show discrepancies: seven tree species found in the first period were not found in the later period. Reversely, 15 tree species were found in the later period, and these did not appear in the first period.

Potential Bias

Influences on vegetation dynamics in forest inventory plots can find their origin in machete damage on young stands, if untrained personnel visit the plot area. Hence all forestry staff were made aware to the issue and trained to reduce damage to the vegetation, when within 30 m of the plot centre. Furthermore, field personnel were trained to keep notes on data sheets whenever damage could not be prevented (e.g. in littoral forests).

Accuracy issues with the GPS device

Throughout the measurement period, issues with the GPS (GARMIN Monterra) were encountered. The accuracy level of 3-6 m led to errors in the establishment of the plots' centre and the plotted tree arrangement contained large spatial errors (Fig. 4.4.6m). We recommended to buy a high Accuracy GPS device (e.g. Trimble R2), which would help increase the accuracy.

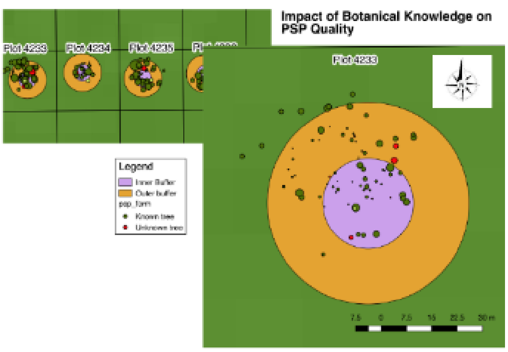


***Fig. 4.4.6m** Accuracy issues with the GPS device within PSP (T. Schmid, 2018)*

Openforis Collect

Fig. 4.4.6n *Inventoried tree (cf. Ceiba sp.) in one of the FCFR PSP (2018*

Starting in February 2017, the Openforis Collect app was installed on several GARMIN Monterra to insert the forest inventory data digitally. Performance issues with the GARMIN Monterra were encountered, especially when larger data files were stored locally on the GPS. Furthermore, adjustments to the survey files rendered data complicated, as no field could be deleted without risking that older data become inaccessible.

After an introduction had been given to the forest inventory team, and after some initial hiccups, the app was regarded as being a useful addition that facilitated work and improved data quality. Unfortunately, the app had a bug in 2019, which was not fixed by the local forest inventory team, while external experts were not informed about the issue. As a result, inventories were carried out by hand again.

Clustering of inventory plots

The data collected so far has to be viewed as pilot data. It does serve the purpose of fine-tuning processes, which are required to run a professional forest inventory. The current data set, however, does not yet give an accurate view of the forest structure of the North-eastern Biological Corridor due to the large number of clusters. The data starting from 2019 can be included in the final forest inventory, but this will depend on CSFI's future forest management strategy, as well as the activities that will legally be allowed by the future zoning of the North-eastern Biological Corridor and the respective statutory requirements.

Comparison of the two sampling periods

The two sampling periods, 2017 - 2018 and 2019 - 2020, resulted in similar numbers regarding stem number, basal area and volume (Table 2). Variations were nevertheless observed with regard to dominance and frequency of trees. This can be brought back to a more representative spread of the plots throughout the North-eastern Biological corridor in the period from 2019 - 2020, whereas the plots in the 2017 – 2018 date subset had been clustered in Freshwater Creek FR.

4.4.7 Stock and forest survey 2014 – 2015

***Fig. 4.4.7a** FCFR Forest Inventory Team 2014*

4.4.7.1 Stock and forest survey 2014

In 2014, a total of nine hectares was surveyed. A stock survey was carried out, which means that only trees of economic or ecological interest were measured. A total of 827 trees with a DBH bigger than 20cm was measured and - when possible - identified. Tab 4.4.7a gives an overview over the various survey plots. Tree quality was categorized as follows: bad, fair/nice, good, special, habitat. Despite high logging activities in the past, there are still 72 trees with a DBH higher than 50cm out of which 26 were recorded as being good or nice (Fig 4.4.7b).

Block	Plot ID	Trees per Plot	Santa Maria	Black Poisonwood	Mahogany	Machich
1	PP1.1	106	3	4	2	0
3	6AB	32	2	1	0	5
3	HC1A	58	14	15	0	0
1	SS1AB	147	11	17	5	6
3	SS3A1	71	11	4	0	0
3	SS3A2	97	11	5	1	0
3	SS3A3	118	2	1	4	6
3	SS3A4	102	6	3	1	0
3	SS3A5	97	0	5	2	10
	Total	828	60	55	15	27
	Mean / ha	92	7	6	2	3

***Tab. 4.4.7a** Stock survey overview 2014 (P.Walther, S.Hobi, 2015)*

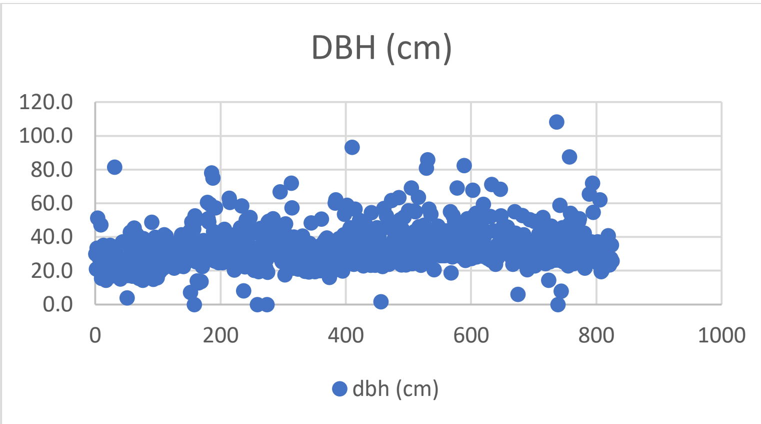


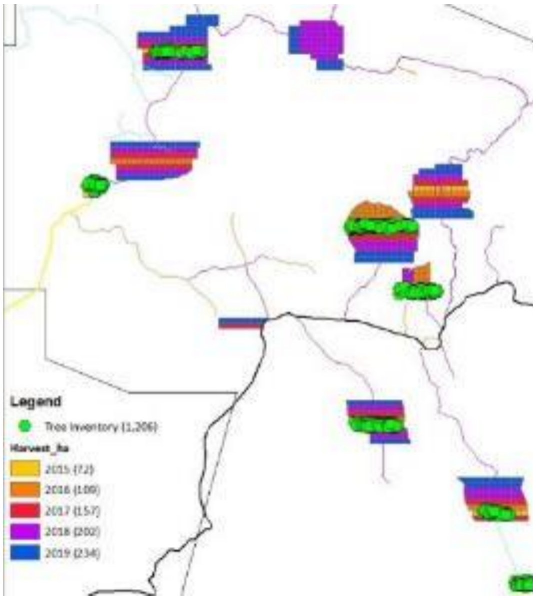
***Fig. 4.4.7b** DBH distribution of all 827 trees recorded in the nine hectares.*

Nr. of Species	Tree Species	Nr of Trees
1	unidentified	227
2	Negrito	84
3	Red gumbolimbo	60
4	Santa Maria	60
5	Black Poisonwood	55
6	Warreewood	55
7	Sapodilla	45
8	Santo Domingo	38
9	Yax`nik/ Fiddlewood	30
10	Machich	28
11	White Gumbolimbo	20
12	Redwood	16
13	Bob (Coccoloba sp.)	14
14	Mahogany	15
15	Ramon	13
16	Sapote Macho	12
17	Bay Leaf	11
18	Hobo	8
19	Mamecilo	8
20	Bullet Tree	7
21	Copal	5
22	Pee	5
23	Strangler Fig	4
24	Red Sillion	3
25	Rosewood	3
26	Botan Wano	1

***Tab. 4.4.7b** Overview of recorded trees within 9 ha of stock survey*

4.4.7.2 Stock and forest survey 2015

In 2015, a stock and forest survey was carried out in a total of 53 hectares and 1778 trees were recorded. Table 12 gives an overview over the classified and measured trees in each area of the reserve.



Tree species	Nr. Of trees	Trees per plot	FT	ST	HNY
Bastard Rosewood	55	1.0	50	4	1
Black Poisonwood	320	6.0	267	29	21
Bullet tree	3	0.1	0	0	3
Katal'ox	57	1.1	45	6	6
Machich	112	2.1	86	16	9
Mahogany	131	2.5	0	130	1
Malerio	30	0.6	29	0	1
Red Sillion	117	2.2	79	26	12
Santa Maria	206	3.9	163	31	12
White Gumbolimbo	17	0.3	0	0	17

***Tab 4.4.7c** Number of valuable timber trees and share of FT, ST and HNY*

***Fig 4.4.7c** Planned areas to conduct a stock survey (2015-2019). The green points show trees measured trees 2015. Some hectares could not be measured as they were actually wetlands. In one case, the road continued much more than mapped, which allowed for a stock survey to be conducted in a new area to the South-East (S.Hobi 2015).*

Area	Nr. of Plots	Nr. of Trees	Nr. of trees per plot	FT per plot	ST per plot	HNY per plot	Volume of HNY per plot [m3]
San Juan	10	604	60.4	30.2	7.1	17.4	3.5
Cacaw	15	250	16.7	8.0	5.3	2.9	0.8
Viejo San Juan	8	247	30.9	22.8	3.8	3.8	1.4
Catbird	8	103	12.9	6.1	3.0	2.9	0.7
Milla 7	12	190	15.8	8.0	3.9	2.4	0.4
Total/Average	53	1394	27.3	15.0	4.6	5.9	1.4

***Tab 4.4.7.d** Summary of stock survey results*

Among the valuable tree species, *Metopium brownei* was the most abundant followed by *Callophylum brasiliense* (Santa Maria) and *Swietenia macrophylla*. The latter was more abundant than *Pouteria* spp., *Lucuma* & *Sideroxylon* and Machich, but only because trees with a DBH<20cm were taken into account. Hence, more than two *Swietenia macrophylla* per hectare are still present. With the exception of *Dalbergia stevensonii*, all high price timber species are potentially present within FCFR.

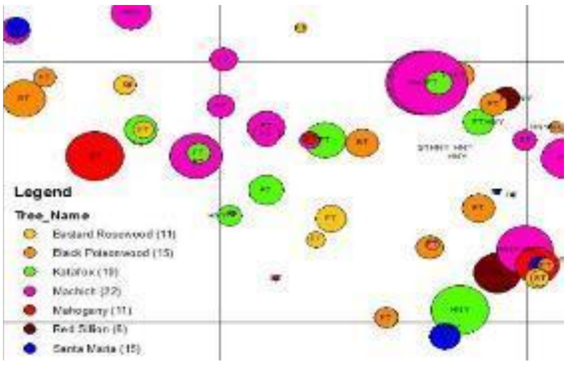


***Fig 4.4.7d** After stock surveys have been carried out, trees can be located at a one-hectare level. The size of the circle depends on the DBH of each tree.*

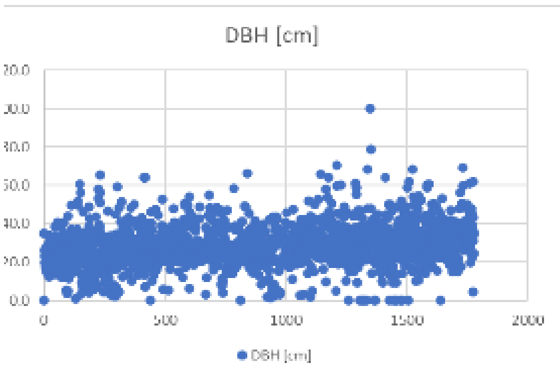


***Fig 4.4.7e** DBH distribution of 1778 trees in the 53 hectares measured.*

4.4.8 Conclusion and recommendations for CSFI Forest Inventory

Fig. 4.4.8 *FCFR Forest Inventory Team 2016 in front of an inventoried Chicle tree*

The forest inventory data collected provide data-based evidence of initial stand assessment from 2014 onwards:

- The forest is composed of naturally occurring, site-appropriate tree species. Emergent trees, valuable for structure and biodiversity, are sporadically still present within FCFR.
- Trees with good economic value of at least 50 cm are rare due to over-extraction by selective logging or falling during hurricanes and tropical storms.
- The last logging concessions focused solely on the extraction of valuable trees, with no regard for sustainability or the silvicultural development of future, high-quality and stable forest stands
- A large number of valuable and target tree species with DBH from 30-50cm will grow into higher diameter classes within the next 10 -20 years.
- The growth, quality and stability of these future forest stands could be optimized through silvicultural selection and interventions.

A forest inventory was and is a central key element to ensure the sustainability of forest management, but also to scientifically describe and analyze forest ecosystems and their dynamics. In the NEBC, even without forest management or silvicultural measures, the future forest development in the context of climate change is of particular interest. Should a forest inventory project be continued, the objectives, budget, resources and implementation should be defined as a long-term endeavor within the organization. The CSFI SFM forest inventory project should thus be scaled towards new objectives for conservation and/or forest ecosystem monitoring. Synergies with the Belize National Forest Inventory or the REDD+ project should be sought and developed.

The NEBC's remote sensing and spectral analysis should be revisited and updated based on the latest data and technologies. Spectral analysis of drone and satellite data should be combined with terrestrial forest inventory data to produce more accurate stand and vegetation maps. LIDAR sensors hold great potential in this regard.

The permanently established plots of the national forest inventory (5 * 1 ha plots) should be analyzed, be it by FD or an external consultant. In particular, growth and dynamics of the plots between the 1998 and 2015/16 surveys should be carefully compared, and newly established plots should be evaluated. Adding additional plots is something that could be discussed with the FD. An evaluation of the 2008 FD forest inventory, before the last logging concession, would be interesting to carry out, as it may allow further comparisons.

The classic Stock and Forest Survey is a suitable instrument to roughly record the economic as well as ecological potential of forest stands, while also allowing for recommendations for silvicultural action and inventories of future seed or habitat trees. Should no silvicultural measures or forest stand management be planned in the future, this inventory method can be discontinued. Special individual trees, e.g. of high biological or market value, should however continue to be inventoried by CSFI teams during field missions.

The planned number of PSPs as in the inventory concept could until now not be carried out. If a statistically conclusive statement about the forest structure of the NEBC is not yet possible, the data do, however, give a good general idea as to the state of said forests. If future assessments are to be made, one should consider that circular PSPs are easier to install in tropical rainforests than square ones. The PSPs, which are smaller in area and more efficient to set up, have the advantage over the 1-ha plots in that heterogeneous forests can be described in a statistically more objective way. These permanently established forest inventory plots, if measured again after a few years, can provide valuable information on growth or changes in forest ecosystems, especially when considering upcoming dynamics related to climate change. The original CSFI PSP inventory concept has the advantage that particular forest types, such as the dry coastal forests of Shipstern, can actually be statistically evaluated using the same inventories based on the same grids (e.g., 500m or 100m network). Data management, project management, as well as human and material resources are key elements that need to be reevaluated if long-term forest inventories are part of future strategies and plans for the protected areas managed by CSFI.

5 Forest ecosystem health and resilience

***Fig. 5a** Illegal agriculture field within FCFR in 2014*

During the project phase 2014 - 2020, the forest stands of FCFR seemed both healthy and resilient, at least visually. For example, no widespread death or failure of stand units could be documented. However, the loss of individual trees or groups of trees due to windfall or other natural factors was observed. In normal cases, gaps and clearings regenerate with secondary forest vegetation, and this within a few years. However, changing precipitation patterns and recurring extreme climatic events, exacerbated by climate change, may in future threaten the resilience and vitality of individual tree species against natural disturbances. Current data would need to be expanded over several years to give a first assessment of the effects of climate change within CSFI's managed forests. A positive aspect is that drier or wetter habitats can now effectively migrate along the corridor system, should climate change dictate them to do so. In that scenario, potential silvicultural measures to help forest adapt to climate change would have to be defined, if either relevant or needed.

The greatest threat to the FCFR forest ecosystem in the short and medium term is currently anthropogenic. Particularly at reserve boundaries, damage to forest stands from fire/smoke from adjacent fire clearing regularly occurs. In addition, nearly 200 ha have been illegally cleared in the last 10 years, to be used for agricultural crops. Some of these degraded forest stands have been restocked with Mahogany through enrichment planting (see references).

Last but not least, forest reserves have historically been subjected to changes following political decisions. Large parts of Freshwater Creek have been excised, step by step, for agricultural development. The last boundary alignments, together with the creation of the Corridor, will hopefully bring some stability to the forests, providing, of course, that proper management ensures their integrity, year after year.

***Fig. 5b** Illegal agriculture clearing within FCFR in 2014*

***Fig. 5c** Fire clearing on the borders of the NEBC*

6 Forest production

Fig. 6 *Members of the FCFR Project Team 2014 with a Mahogany relict (Ejido Noh- Bec, Quintana Roo, Mexico, 2014)*

"SFM and forest production addresses the objective of maintaining the multiple functions of forests and their capacity to deliver products and environmental services. Such functions and capacity can only be sustained in the long term if forest management is economically and financially viable, environmentally sound and socially acceptable" ITTO, 2016.

6.1 Forest management History

The following section (chapter 6.1) is an excerpt from "Mahogany in Belize: a historical perspective, P.L. Weaver and O.A. Sabido, 1997

The oldest Maya remains at Cuello, Orange Walk District, Belize, date back to 2500 B.C. (Krohn 1987). The Mayan culture prospered, reaching an estimated population of 400,000 to 1 million in Belize (Hartshorn and others 1984). The Mayas managed, influenced, and extensively converted forests for agriculture for 2 millennia until the collapse of civilization (ca. 950 AD). Presumably, many of the "primary forests" that European settlers found 600 hundred years later from the 16th century onward resulted from these anthropogenic and natural disturbances of ancient forest ecosystems.

In 1502 Columbus explored the Bay of Honduras and in 1524 Cortez apparently passed through southern Belize during an overland march from Mexico City to Honduras (Wright and others 1959). 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). From 1638 to 1900, the existence of Belize depended on the export of forest products. Like many other territories, its economy was based on a single resource-in this case, timber.

During the Convention of London (1786) a pact with the Spanish was signed which forbid the British to establish real settlements and agriculture in Belize. This forced them to focus on natural resources that the country of Belize presented them with (R. Pemberton, 2012). The Mahogany trade began by 1771, it had supplanted logwood as the country's chief product. The earliest Belizean laws, adopted around 1665 for logwood extraction in un-surveyed areas, were agreements made by loggers (Hooper 1887, Wright et al. 1959).

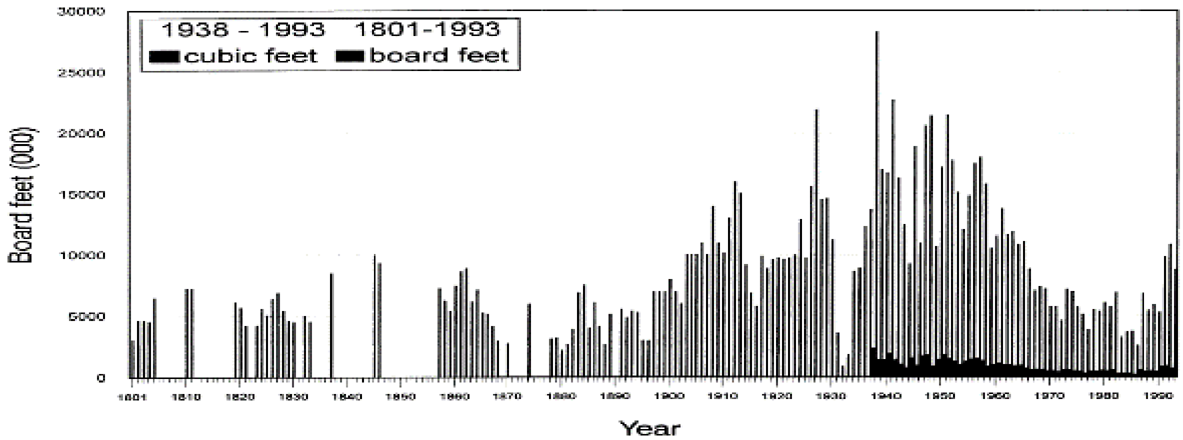


Fig. 6.1 *Chronology of Mahogany exports from Belize 1801 to 1993. Summary from colonial and forestry annual reports. (P.L. Weaver and O.A. Sabido, 1997)*

In 1774, Belize's largest recorded Mahogany, measuring 3.65 m in diameter, was felled (Peet 1954). 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, and to 15 percent in 1963 (Furley 1968). 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).

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 forestry program, initiated under the Forest Trust in 1923 and continued under the Forest Department in 1935 is also the beginning of the freshwater Creek Forest Reserve (1923).

Recent timber production (m^3) statistics for Belize

	1977	1978	1979	1980	1981	1982
Mahogany and Cedar	9,571	13,662	13,441	15,148	14,220	17,215
Pine	4,307	2,943	3,797	2,151	4,123	5,850
2° Hardwoods	13,895	15,514	17,855	23,957	19,697	18,750
Rosewood	504	258	3,509	2,541	357	458
Ziricote	5	126	18	36	38	55
Logwood	-	-	-	-	-	132
Totals	28,282	32,503	38,620	43,833	38,435	42,460

***Data provided by O. Rosado, Forest Department**

Tab 6.1 *Of Interest is the high amount of secondary hardwoods. Unfortunately, no information about species could be found*

6.2 Historical SFM within FCFR

Without including the millennia-old use of the forest by the Maya, the timber resources and especially Mahogany have been managed / harvested in FCFR since the 17th and 18th centuries. In 1923, the FCFR reserve was gazetted with the objective of sustainable forest management. At that time, it had 29`630 ha, almost twice its current size. Mahogany density in the reserve between 1930 and 1940 was 4.7 S.m / ha (Lindo, 1967), which is twice that shown by the most recent CSFI FCFR forest inventory data (2.5 S.m. / ha).

The Mayas and subsequently the British silviculturists have historically tried to artificially enrich their valuable timber tree species. The British Forestry Commission enriched Belize’s forests with Mahogany. The following information refers to the FCFR:

Location and years	Seedlings	Saplings	Poles / trees	Total
Freshwater Creek 1926-27, 1939-42	4`817	13`475	16`435	34`727

Tab 6.2 *FCFR Mahogany enrichment 1926-27, 1939-42*

6.3 Forest roads and forestry Infrastructure

Over the past decades, a network of forest roads has been built within FCFR. This network is in poor condition, but important for future forest management. From 2014 onwards, various forest roads and skid trails within the Reserve were assessed, categorized and inventoried. Unfortunately, the network of skid trails was uncoordinated, and heavy machinery caused damage by compressing the sensitive forest soil. Poor condition of roads may also have adverse effects for forest management, mostly in terms of safety, efficiency and sustainability. One of CSFI’s important objectives in future management is to avoid any expansion of damage to the forest floor by making use and improving of existing skid trails and road network layout. In other words, new trails and roads should not be added unless absolutely necessary. From 2015 onwards, FCFR headquarters were expanded with a field office, a workshop and living spaces for the FCFR team, a nursery and simple tourism infrastructure.

6.4 Silviculture

Fig. 6.3 SFM and RIL Training, FCFR 2018 (Photo: T. Schmid)

"Silviculture is the art and science of controlling the establishment, growth, composition, health, resilience, stability and quality of forests to meet the diverse needs and values of both ecosystem and society on a sustainable basis".

6.4.1 Goals and Objectives

The recommended silvicultural strategy is based on permanent forestry or plenter forestry systems with a return period of 6 - 10 years, involving careful interventions. In some areas to be defined, target diameter felling with a rotation period of 25 years can be envisaged, but in that case without interventions involving silvicultural thinnings.

Overall Goals

- Conservation and long-term management of local Mahogany and other target tree species phenotypes (by ensuring a selection of seed trees and rejuvenation units / ha)
- Develop and implement adequate silvicultural measures to increase density, quality, resilience, health and stability of various target trees
- Increase of target species stem number (n / ha), stock volume (m^3/ ha), basal area (m^2/ ha), old growth DBH classes (60cm +) as well as a sustainable age class distribution
- Thinning and partial extraction of selected trees
- Production of high-quality and FSC-certified timber a basis for a local, forest-based value chain
- Long-term contribution to the financing of protected areas and the sustainable livelihoods of surrounding communities
- Development and implementation of an innovative SFM pilot project to serve as a model for Belize

FCFR Project Objectives

- Enrichment of gaps created by previous logging concessions as well as illegal agricultural clearances in FCFR with Mahogany and other target species
- Definition of high quality and vital seed trees in FCFR, from which phenological data are collected annually
- Development of tree nursery infrastructure and annual production of 10 - 20`000 Mahogany and other target tree species from locally harvested seeds of good quality
- Planting of 50 – 100`000 valuable timber trees inside and outside FCFR between 2016 and 2020
- Training of staff and building of capacities in line with project goals
- Long-term silvicultural study and scientific evaluation of the success of tree planting (Mahogany and other species)
- Compilation of knowledge and experience, in preparation for future replication.
- Model and silvicultural recommendations for enrichment plantations and thinning concepts for Mahogany

Silvicultural production targets

- Production of stable, resilient and high-quality Mahogany and other target tree species as single trees or in groups of trees within FCFR
- Reach target DBH or emergent phase in the shortest possible time
- Production of a high-quality subsidiary stock for intermediate use in thinning operations

6.4.2 Silvicultural treatments

Fig. 6.3.2a *Naturally established Mahogany within FCFR, after tending (marked blue, 2019)*

The Freshwater Creek Forest Reserve is clearly not a "pristine" primary forest, as it has been managed for forestry since the 17th or 18th century, and is today crisscrossed by a historical forest road network. In addition, illegal logging and clearing, as well as tropical storms, have dynamically shaped the forest ecosystem. If the forest reserve was indeed long managed as a PFE, several valuable timber tree species such as Mahogany, were overexploited over the whole period. Hardly any investment was ever made to increase the value and stability of the remaining stands. Emergent trees, important for tropical forest ecosystems, are missing as a result of overextraction, and probably to a lesser degree by wind damage. Heavy interventions as well as short logging rotations have strongly influenced age class distribution, which has rejuvenated markedly. From a forestry or silvicultural point of view, FCFR is a degraded production forest in a development phase. The silvicultural measures aim at establishing vital, resilient, stable and high-quality forest stands. This goal can be reached through the implementation of the following:

Stand establishment

New rejuvenation areas created by large-scale harvest are quite obviously not to take place in the coming 10 to 20 years, unless by natural calamities. The goal is thus to keep the existing regeneration ongoing, while selecting and freeing future trees. In many of these young forest areas, individual valuable timber tree species have reestablished naturally (Fig 6.3.2a). It shows the potential of natural rejuvenation of target species enhanced by silvicultural treatments as well as the establishment of future stands, without actually planting. This, however, will require the presence of mother trees over the entire area, at a density that needs to be identified (large emergent trees having a greater capacity at dispersing their seed). In areas devoid of or with poor natural regeneration of target tree species, enrichment plantings can be carried out, e.g. Mahoganies or other high-value hardwoods.

***Fig*. 6.3.2b** FCFR Team 2020 inside a four-year-old Mahogany enrichment plot

CSFI carried out a pilot project of Mahogany enrichment plantings between 2014 and 2020 (Fig 6.3.2b). A detailed technical project report including evaluation of the results can be found in the references) and can be viewed as a digital web report at this link: https://arcg.is/jreGS0

Maintenance of young forests

Fig. 6.3.2c *Head ranger Rene Galindo tending to a young forest stand*

The maintenance and tending of young tropical forest stands is a demanding and labor-intensive silvicultural measure. However, considering the local labor costs and the potential increase in value and growth of future forest stands / individual trees, it is an efficient one. The valuable timber tree species, which rejuvenate in canopy gaps are rapidly threatened by heavy secondary forest vegetation, especially lianas. With one or two early maintenance interventions in the first 10 years, growth, stability and quality can be significantly increased. In addition, the species composition in regeneration units can be decisively influenced in this development phase.

Silvicultural thinning operations

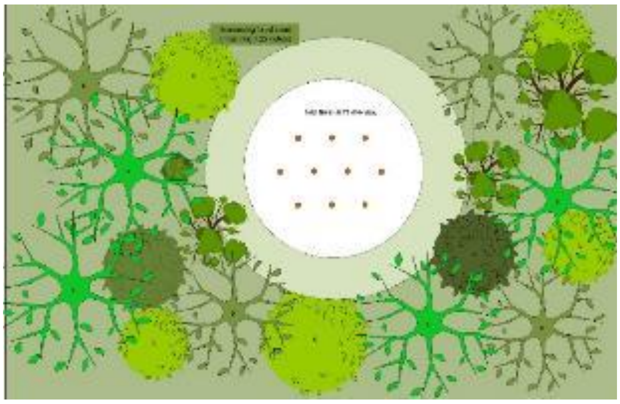


Fig. 6.3.2d *Before thinning the surrounding stand*

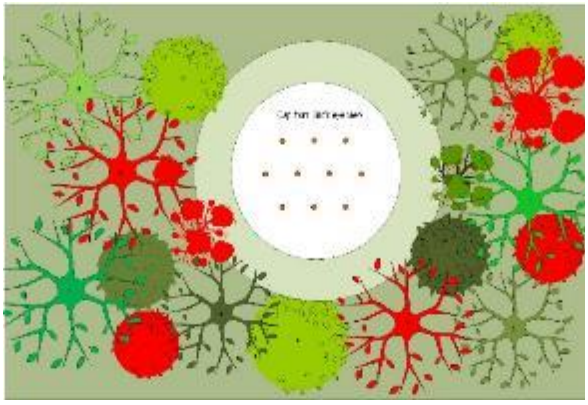


Fig. 6.3.2e *After thinning (the thinning harvest is shown in red)*

If the objective is to increase growth, quality and stability of selected future trees, thinning measures are recommended. Per hectare, 20 - 60 future trees should be defined and the most urgent competitors as well as lianas should be removed or harvested at several intervals. The future trees can be selected for both ecological or economic reasons. Thinning is also recommended in planting areas. In addition, unstable trees that constitute a threat to young stands, should be removed and harvested whenever necessary.

Fig.6.3.2f *The crown of this beautiful Mahogany (left) is strongly suppressed by a competition.*

Fig.6.3.2g *The competition tree of this Mahogany was girdled*

Fig.6.3.2h *Removal of vines around a Mahogany*

6.4.3 Silvicultural research and pilot project

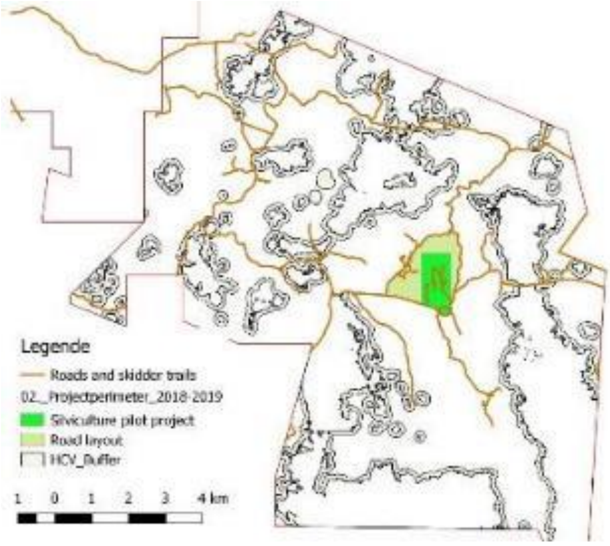


Fig. 6.3.3a *Overview FCFR silvicultural pilot area*

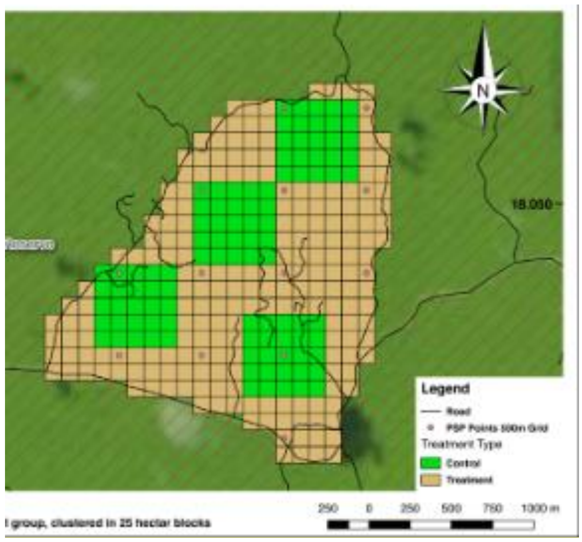


Fig. 6.3.3b *Detail map with reference plots without intervention (green)*

In combination with the original forest warden apprenticeship project and training courses, a silvicultural pilot project was planned at FCFR. In a test area, all described forest inventory methods were to be carried out in a condensed form. From the beginning, reference areas with no treatments were to be identified, in which only forest inventory plots were to be established (Fig 6.3.3b). In the silvicultural area, all silvicultural measures as described above were to be carried out and thoroughly documented.

6.5 FCFR Timber Products

About 20 timber species have been identified so far within FCFR (S. Hobi 2015). As he described in his report, "*understanding of local and international timber markets is fundamental to define forest management activities. Key species has to be specified, before starting stock surveys. Valuable timber species needs to be defined to increase their number, their DBH and their quality on a long term. Knowledge about timber market is low for the FCFR Project. No trading relations exist. Knowledge about the timber prices is required, to estimate the remaining value of the forest.*

In January 2015, Mr. Usher from the FD explained that the six timber species in table 4 are of special economical interest.

Latin	English	Local	min DBH [cm]	Abundancy [Nr/ha] (Stock Survey 2015)
Swietenia macrophylla	Big leaved Mahogany	Caoba	65	1.5
Metopium brownei	Black Poisonwood	Chechem	50	6
Platymiscium yucatanum		Granadillo	45	low
Astronium graveolens		Hobillo	none	low
Cordia dodecandra		Ziricote, Zericote	none	low
Cedrela mexicana	Spanish Cedar	Cedro	65	Low / none?

Tab. 6.3a: *High price timber species according Me, Usher, FD, 2015*

In March 2015, Dr. Cho of the FD confirmed the high economic importance of these species. He mentioned that they were exported as round wood since no high quality sawmill is present in Belize. He estimated a price of around 6 Bz$fbm (1270 US$ / m³) on the international market, which is about three to six times higher than the local prices.

To improve knowledge on local timber markets, two Mennonite sawmills around FCFR were visited. Mr. Peters' sawmill is located in Shipyard. He offers one price for Swietenia macrophylla and Cedrela mexicana (2.3 Bz$fbm-1 (487 US$/m³) and a second price for all other tree species (1.1 Bz$fbm-1 (233 US$/m³). He does not buy Metopium brownei because it is affecting his employees. The owner buys all species listed in table 6 and pays 1.05 Bz$fbm-1 (222 US$m-3). If wood is scarce, he also buys Dendropanax arboreus and sometimes even Simarouba glauca (Negrito) for a lower price of 0.8 Bz$fbm-1 (169 US$m-3). He did reveal that his resell price is at 1.50 Bz$fbm-1 (317 US$m-3).

Latin	English	Local	min DBH [cm]	Price [US$/m³]
Lonchocarpus castilloi	Cabbage Bark (black)	Machich	60	222
Pouteria mammosa	-	Mammey		222
Erythroxylon aerolatum / Mosquitoxylum jamaicense	Redwood	Redwood	45	222
Pouteria spp. , Lucuma & Sideroxylon	Red Sillion	Red Sillion	45	222
Calophylum brasilense	-	Santa Maria	60	222
Bucida buceras	Bullet Tree	Pucte / Jacaro	60	222
Manilkara zapota	Sapodilla	Chicle	60	222
Lucuma & Sideroxylon spp.	White Sillion	Sillion blanco	45	222
Andira inermis	Yellow Cabbage Bark	Machich blanco	none	222
Manilkara chicle / Achras Chicle	-	Chicle Macho	60	222
Lysiloma cf. bahamensis	Caribbean Walnut	Tzalam	none	222
Swartzia cubensis	Katalox	Katal'ox	none	222
Swartzia spp. / S. leiocalycina	Wamara	Bastard Rosewood	none	222
Aspidosperma megalocarpon	Mylady White	Malerio	?	222
Dendropanax arboreus	White Gumbolimbo	Chaka Blanco	none	169

Tab. 6.3b *Tree species of medium economic interest (S. Hobi 2015)*

There are about twenty different tree species of economic interest. Little information about timber prices is available. The Belizean market seems to be rather poorly developed. There seems to be no interest for lower quality trunks, although locals indicate that wood from many more species can actually be used for various purposes. Wood waste is not further processed, for example to plywood. Although people still cook using wood as fuel, no energy wood is actually sold.

The installation of a high quality saw mill in Belize is of mayor importance to increase the value of the products within the region. Due to the high price gap between local and international market it is highly recommended to achieve the required standards to export lumber. Additionally, further markets need to be developed to profit from other, less valuable tree species and wood waste. All these factors can multiply the present value of the FCFR and are therefore significantly influencing the profitability of harvesting activities.

Surprisingly, both sawmills won't buy Metopium brownei. The high price for Black Poisonwood can only be achieved with trees of a high quality, sold as round wood at the international market. It is highly recommended to further investigate about this species. Since it cannot be sold at the local market but is expect to achieve a high price at the international market, this could be a key species providing an important share of income. Knowledge about the quality criteria are therefore highly required to ensure the selection of the right trees. The presented price list for local and international markets still needs to be further improved and continuously adopted.

6.5.1 Evaluation of the forest inventory according to timber products

The data of the forest inventory show that stronger diameter classes of most economically interesting valuable timber tree species from 50 cm BHD are missing, but are present in the diameter classes between 20 and 50 cm BHD. A commercial, polycyclic target diameter harvest in the next 10 to 20 years is therefore neither realistic nor does it make much sense, this for ecological, economic but also silvicultural reasons. Insofar as the forest stands are thinned and competitors are removed from selected future trees, a yield can be generated by thinning. For example, the economically interesting value timber tree species black poisonwood (*Metopium brownei*) has a high number of stems/ha in FCFR and also trees over 50 cm BHD are present. These often crowd around other target tree species such as Mahogany, and could thus be harvested to favor future trees. The same statement can be made for Warree Wood (*Caesalpinia gaumeri*) and others. Thinning can thus be a useful tool to build up healthy, stable and high-quality forest stands, while also directing the increment of growth to selected future trees. Clearly, however, any harvest will mainly be suitable as niche products, and not as commercially interesting harvests for national or international lumber markets. Belizean NGOs such as CSFI could cover their demand for wood resources from sustainable sources, and in particular substitute raw materials such as concrete when building new infrastructure in the protected areas. Special mention should be made of decorative wood assortments, for example for the tourism industry. The provision of firewood or by products into bio-char may also be taken into consideration.

Fig. 6.3.1 *Examples of decorative wood niche products in the Caribbean tourism industry.*

From an economic perspective, the forestry return from the forests of FCFR will, for the time being, remain modest. Revenues may however allow for the financing of part or all forest maintenance activities and form the basis for a forest-based, local value chain. That said, minimal DBH and other felling rules will have to be discussed with and approved by FD.

6.6 Non-Timber Forest Products (NTFP)

Non-timber forest products have been harvested and cultivated by local communities for thousands of years and have always been part of their livelihood. The British colonial administration also harvested and exported NTFPs. Today, some NTFPs remain of great importance to local communities and/or touristic infrastructure. Consequently, some NTFPs also have economic potential and can be part of a sustainable forest-based value chain. The marketing of chicle, crafts using woven lianas, medical plants or honey production by Maya communities in the tri-national Selva Maya project are good examples. A detailed report on Belize's forest products can be found in the references ("Goods from the Woods: The Harvest of Timber and Non-Timber Forest Products in Belize," R. Heinzmann at all). A table of NTFPs available in the NEBC with their uses are in developing). A checklist for sustainable harvesting and management of Huano Palm leaves (Bay leaf - *Sabal mauritiiformis* and *S. yapa)* was developed. Michele Bühler, beekeeper and forest engineer from Switzerland, has prepared a baseline study for honey production in NEBC (see references). CSFI intends to develop a baseline feasibility study and marketing concept for the sustainable harvest of NTFPs within the NEBC system.

Fig.6.5a *The chicle tree has been harvested and managed for centuries. In the FCFR there are many trees still bearing the mark of past harvesting.*

Fig.6.5b *Lianas have always been used for constructions, as binding material as well as for weaving. Certain species also as a medicinal plant.*

Fig.6.5.c *Huano leaves are still much used as roof covers. If domestic use is becoming less, the tourism industry and its use of traditional infrastructures creates a high demand.*

Fig 6.5.d *Copal Resin was used by the Mayans as a traditional and spiritual incense medium. It is still used and marketed for this purpose today.*

6.7 Sustainable Harvesting of forest products and reduced impact Logging (RIL)

***Fig. 6.7a** FCFR Forestry team 2018*

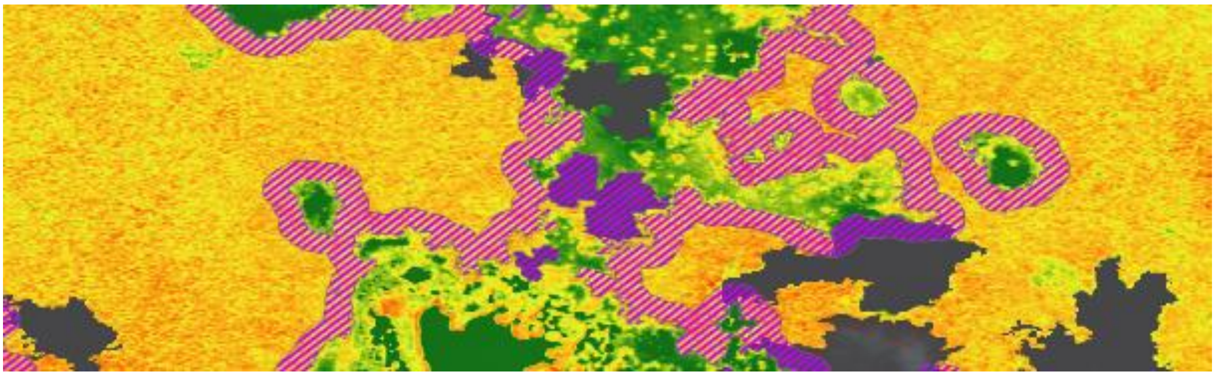
The sustainable management and use of timber and non-timber forest products should be based on sound forest inventory data as well as a management plan. While an overall concept for sustainability still has to be developed, initial thoughts have been gathered with regard to the harvesting of Huano, a most promising NTPF because of existing demand and the lack of an offer of certified sustainable leaves in Belize. In developing systems, care should be given to always separate enforcement and harvesting teams, to ensure mutual control and good governance at all times. For the optimization, transparency and integrity of SFM, it is also recommended to separate the forest service into sovereign and operational tasks and competencies units (B. Pauli, HAFL).

***Fig. 6.7b** Instruction of safety aspects of RIL*

***Fig. 6.7c** Instruction of directional felling and RIL*

The FCFR team was trained in some basics of SFM and RIL in 2014 to 2020. Basic forestry training was planned as part of the forest warden apprenticeship pilot project. However, since the north-eastern Biological Corridor came into existence, further investments in resources, knowhow and equipment for SFM & RIL are currently on hold, pending the final statutory rules and zonings for the corridor.

6.8 Forest management Plan



***6.8** FCFR HCVs classification based on RapidEye data (violet are the hundred-meter buffer around wet forest communities and wetlands)*

Since 2014, pilot projects, baselines, GIS and documents for an FCFR SFM plan have been developed. CSFI is currently working on an overall management plan for the entire NEBC-Shipstern System. If allowed within defined zones, SFM, RIL, enrichment plantings may resume. The exact scope of such activities will depend on goals and available funding.

7 Forest biological diversity

7.1 CSFI Flora and Fauna Monitoring Program

Fig. 7a *Jaguar within CSFI managed area (Monitoring Team, 2017)*

Fig 7b *This Red-eyed Tree Frog (Agalychnis callidryas) was encountered during the 2014 field mission in FCFR*

In parallel to its forestry activities, CSFI has set up a comprehensive camera-trap monitoring of fauna throughout the protected areas. This has revealed an astounding diversity of wildlife, and helped identify 30 different jaguars (as of March 2021).

Fig. 7c *Unidentified Bromelia within an HCV area of FCFR (2014)*

Over the duration of the project, the botanist Henry Martinez helped improve the quality of species identification within sampling plots, while also adding many taxa to the plant list for the area, under the latest nomenclature. He also trained CSFI personnel in species identification and specimen collection for herbarium purposes.

7.2 Biodiversity concept in near-natural production forests

High Conservation Value Areas (HCVs)

The Freshwater Creek Reserve was mapped in 2014 based on RapidEye spatial data and GPS field surveys. The wetlands and adjacent forest communities adapted to periodic flooding were defined as high conservation value areas (HCVs). (4471 ha = 33.4%). The species- and structure-rich transitional areas towards higher stands of lowland forest communities being often intertwined in a complex mosaic, such areas were included into a unified one-hundred meter buffer (1884 ha = 14.1 %).

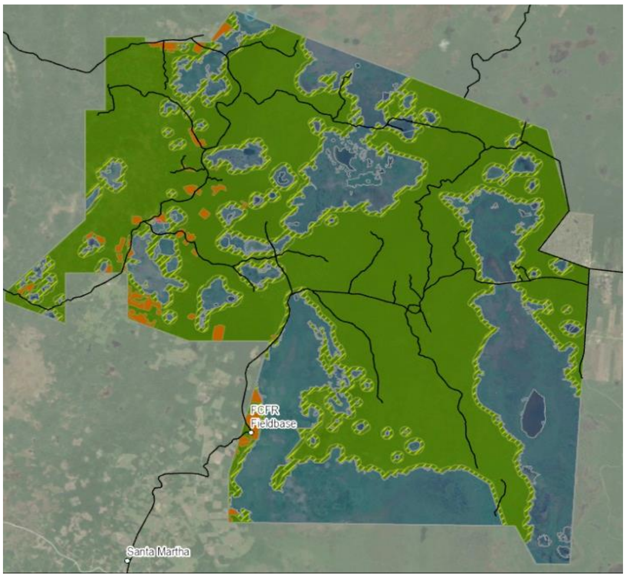


Fig. 7.1a *FCFR HCV and 100 m Buffer*

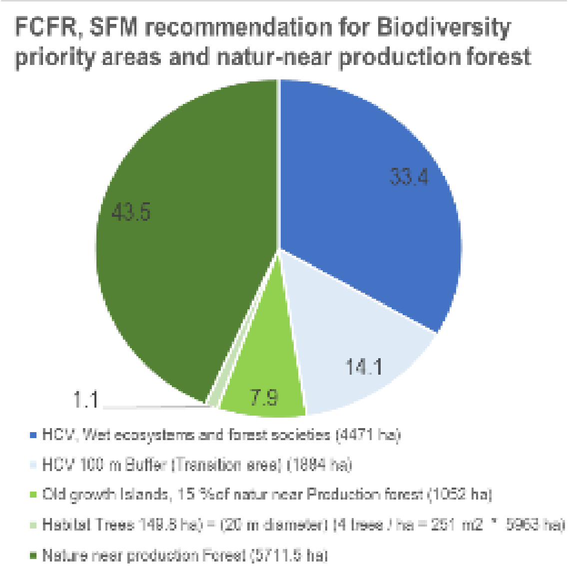


Fig. 7.1b *area statistic of biodiversity and production*

According to this classification, the theoretical near-natural production forest area is 7015 ha or 52.4 percent of FCFR. Thus, 47.6 percent of the FCFR area (6,355 ha) was defined as HCV without forestry intervention. Not defined to date are the possibility of traditional multiple use of NTFPs as well as fishing rights in this HCV area etc. Of the 7,015 hectares of near-natural production forest, 15% would be declared as conservation old-growth forest islands or special forest communities (1,052 ha / (8 % of FCFR area)). Within the remaining production forest area (5,963 ha), every hectare should on average include four habitat trees.

Based on this calculation, out of 13,370 ha of FCFR, almost 7,557 ha (56.5% of the reserve area) are classified as priority areas for biodiversity. As a result, 5,813 ha would be defined as near-natural production forests allowing silvicultural measures (43.5 % of the reserves area). If it is intended to leave standing or lying dead wood within the framework of all forestry activities, more specific enhancement measures for biodiversity or target species in existing ecosystem classes were not addressed in this report. The methodology towards a clear definition of habitat trees and old-growth islands must be finalized. The conservation of genetic variation within specific tree, plant, or animal species is not addressed in this report, although its importance for e.g. Mahogany is intrinsically recognized. In parallel to its forestry activities, CSFI has set up a comprehensive camera-trap monitoring of fauna throughout the protected areas. This has revealed an astounding diversity of wildlife, and helped identify 30 different jaguars (as of March 2021). Over the duration of the project, the botanist Henry Martinez has also added many taxa to the plant list for the area and updated nomenclature to the latest stand.

Fig. 7.1c *Habitat tree close to an archaeological site*

Fig. 7.1d *Epiphytes within FCFR HCV area*

7.3 Buffer zone management and connectivity of protected forest areas

CSFI and ITCF once developed a vision for a "Green Pension Plan". It envisioned to reforest degraded agricultural and/or slash-and-burn areas outside the NEBC as near-natural production or conservation forests or small scale plantation forests. In addition, various agroforestry systems could be implemented in cooperation with local smallholders. Ideally, remaining forest areas outside the NEBC should only be allowed to be converted into agricultural areas under certain conditions. For example, by leaving strips of forest or forest islands, hedges or single or groups of trees. Unfortunately, such endeavors are not supported by any legal instruments. Another option would be to propose certain areas as being only suitable for integral agricultural systems such as traditional small scale slash and burn or other agroforestry systems.

In the long run, it is CSFI's intention to create, in full partnership with the Government, new corridors towards the South-West in order to eventually connect the NEBC System with the Crooked Tree Wildlife Sanctuary. As a matter of fact, Belize is one of the rare countries in the world that still has the capacity to connect the very northern tip of the country with its southern end. However not for long, as conversion of natural landscapes continues.

8 Soil and water protection

Fig. 8a *The Blue Lagoon, a freshwater lagoon / cenote within FCFR*

As described in chapter 6.3, there is a historic forest road network as well as countless, uncoordinated skidder trails within FCFR. In a first step, these should be concluded inventoried and classified. Based on this road layout, the coarse and fine development of the new road layout should be defined in a planned and binding manner. Forest soils are very sensitive to mechanical compaction. In future, machines and vehicles should only move on the defined and improved road network. Winches, cable winches or horses should be used for advancing timber or NTFP to primary or truck roads.

Fig. 8b *Former FCFR Forester P. Walther and former CSFI ecologist Louis Pena discuss impacts of barriers in hydrological ecosystems*

Fig. 8c *On the main road crossing FCFR, only one very small culvert (50 cm diameter) connects the two halves of a lagoon system that was split by the construction of the road.*

The waters and wetlands of FCFR were all systematically classified as HCVs and are thus protected from adverse forestry impacts such as oil spills, etc. This includes, as discussed before a 100-metre buffer zone. The hydrology of the reserve, including cenotes, was not investigated in detail over the years. Interestingly, one feature, namely the FCFR Main road, which cuts through the reserve from East to West, starts to affect water dynamics of the lagoon and wetland system it runs through, mostly because water flows are severely hindered by the absence of decent culverts, except for one that is clearly undersized (50cm diam. only). Potential impacts from rising sea levels or groundwater are also not addressed in this report. The FCFR ranger team has discovered new freshwater sources in recent years. The saltwater / brackish water and freshwater bodies have not conclusively been classified as yet. For example, the Meerman Ecosystem Map defines large lagoons as freshwater even though they are brackish water ecosystems. The cenote systems in the perimeter have not studied in detail.

9 Economic, social and cultural aspects

Economic aspects

CSFI manages protected areas either as their legal owner or under mandate by the Government of Belize, with the financial support of the International Tropical Conservation Fund. Both entities define together long-term strategy and management goals. In addition to ITCF's help, some revenue is generated through tourism activities. A sustainable or ecotourism project is gradually developing, but is not part of the report. Until now, no revenues have been generated through the sustainable management or harvesting of natural resources or ecosystem services.

The evaluation of the FCFR SFM project 2014 - 2020 shows that sustainable management of the FCFR natural resources is feasible and that it bears potential for a small scale forest-based value chain. That's said, the limited area of near-natural production forest within FCFR (5,000 to 7,000 ha), the sustainable potential of timber and non-timber products is of course somewhat limited, due to necessary harvest rotations. This could however be increased by intensifying silvicultural measures within the production forest, or further expansion of SFM activities outside the original FCFR and into the NEBC. However, on a regional level, only little infrastructures and limited capacities for the processing of timber and non-timber forest products are currently available. These would need to be built up, which in turn would create new jobs opportunities for surrounding communities.

Currently, Mennonite communities engaged in export-oriented and intensive agriculture and large landowners in the sugarcane industry are among the main employers for communities around the NEBC. CSFI, with approximately 35 employees is not a negligible actor either, together with a few others within the tourism industry and the government. Ecosystem services of the Shipstern - NEBC system are not yet monetized. On a more symbolic level, hectares of nature and fauna are offered for adoption in the fundraising programs of the ITCF in Europe and America

Social and cultural aspects

Fig. 9a-c *Portraits of people living around the NEBC complex.* ***9d*** *Picture from Quintana roo in Mexico, illustrate some NTFP examples*

CSFI personnel were trained in various SFM topics during several weeks of training in 2014 - 2020. In addition, specialized teams received training from national and international experts in fields as varied as law enforcement, first aid and other emergency procedures, wildlife monitoring, botany, firefighting, etc.

These activities were carried out within a broader vision to eventually build up forestry and forest science knowledge (including the monitoring of biodiversity) as part of a SFM institute at FCFR, including human and material resources. The idea was also to make sure that an FCFR Forest Service would meet international SFM standards, criteria and indicators at all operational and administrative levels within 10 years (ITTO / FSC / CH). Such a project would be designed as a model for SFM in Belize and Central America, and would provide the basis for a local, forest-based, innovative and sustainable value chain and ensure a cornerstone of the UN SDGs for the region and surrounding communities. As a first step, a forest warden apprenticeship project was planned to make sure a professional and qualified team would be available for SFM activities. The most capable and motivated individuals from this team would have been given the opportunity for internal or tertiary forestry education and become SFM or RIL Instructors or teachers. Unfortunately, not all aspects could be developed within the scope of the project, nor did financial resources allow for the start of SFM operations on a larger scale. Turnover within the team also hindered the advancement of the project, as new staff had to be trained.

An ideal vision would entail that the long-term protection of the reserves and ecosystems be financed through the sustainable management of the natural resources, that would provide local communities with alternative, skilled and interesting jobs, in line with SDGs. In a sense and on a modest scale, this has been true for CSFI employees working in enforcement, tourism, monitoring and, in part, in forestry activities within the scope of this project. Unfortunately, given the current depleted state of the forests and the impossibility to immediately start creating revenue from forestry activities (due to over-extraction in past decades), the development of a larger project, involving the creation of further jobs, is at this stage hardly feasible. In future, the multiple-use zones within the NEBC (and possibly also the Warree Bight extension of Shipstern), may offer long-term possibilities. However, these forests would first need to be rehabilitated properly, which in turn will require substantial financing over several years (if not decades) before revenues can actually be generated. This goal must thus be part of a new strategy for SFM in the NEBC, but this goes beyond the scope of this project and report.

Traditional knowledge of and use by local communities

Traditional knowledge about the use of the forest ecosystem was found to be still partially present, but mostly undocumented. Elders confirm that at least some members of the local population have traditionally, in the past decade, harvested NTFPs in FCFR and the NEBC for basic subsistence needs or as additional income. These activities were often illegal, but were sometimes tolerated. Illegal logging and hunting, although illegal, was never acted upon nor sanctioned until CSFI started implementing patrols throughout the protected areas. Within FCFR, illegal clearing for agriculture was noticed from the mid-2000s onwards, often by people not belonging to local communities in the immediate vicinity. Today, no community actually lives inside the boundaries of the former Honey Camp NP or Freshwater Creek. Sacred places or a special spiritual relationship of the local population to the forests within the NEBC are currently not known to exist. However, archeological sites from Mayan times do exist and artefacts are regularly discovered within the NEBC complex.

Fig. 9e *Children from a local community visiting Shipstern Headquarters (2014)*

Rights of local communities and participation in forest management

All lands within the Shipstern-NEBC being either privately owned (and under trust agreement) or property of the Government of Belize and declared as part of the corridor, no special right by local communities exist over said lands. The community of Fireburn is an exception in that it owns land within the corridor. Under the management plan currently being developed, a multiple-zone use is to be contractually defined and implemented around the Fireburn lands, as a co-management agreement. Prior to the legal establishment of the Corridor, the Government and CSFI jointly organized a series of stakeholders' meetings, in order to ensure prior and informed consent by all communities bordering the corridor.

10 Project, GIS and Data management

The SFM planning principles with a participatory involvement of the relevant stakeholder groups are usually defined in a binding 25-year objective and management strategy of the FMUs. In line with this, a 1-year, 5-year and 15-year plan and corresponding evaluation reports should be developed. For internal SFM project evaluation and goal setting, as well for reporting; the document “Criteria and Indicators for the Sustainable Management of Tropical Forests”, published by the ITTO in 2016, is much recommended.

Long-term oriented GIS and data management as well as archiving concepts or access to this knowledge is a key element for SFM projects. Short-term changes of databases as well as software applications can lead to data loss during data migration. In addition, employees have to be trained in the use of new applications, which absorbs resources. The interface from field to back office teams has proven to be a crucial and sensitive work process, and so has data quality and integrity. Digital data capture and automated data transfer have great potential in this regard, but require a forward-looking and well-planned concept. Based on the pilot phase 2014-2020, with the evaluation of various software applications as well as manual data collection, a cross-organizational use of the cloud-based Microsoft Office 365 solutions and the ArcGIS platform is recommended. Thereby, all project employees as well as external relevant persons should receive a personal account. Permissions and authorization hierarchy, data security and data architecture are also key elements. For the implementation of such a digital system, external experts should be involved in order to develop and set up systems based on the needs and requirements of the organization. The reduction of cash flows with a traceable system for digital financial flows (e.g. credit cards or apps for expenses, fuel purchases, etc.), if at all applicable in Belize, would ensure transparency on the one hand and reduce administrative burdens on the other. These measures can contribute to internal and external quality management and controlling within the organization and optimize internal and external communication and knowledge transfer/management.

For the FCFR SFM Project and Evaluation Report 2020, the image, GIS, and document data and databases were structured as shown below:

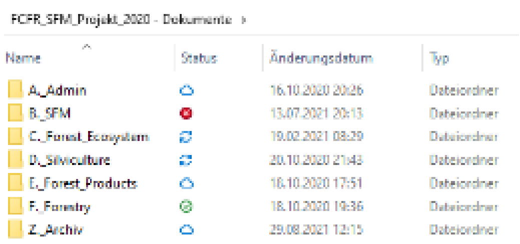


Fig. 13a Data structure main level FCFR SFM project

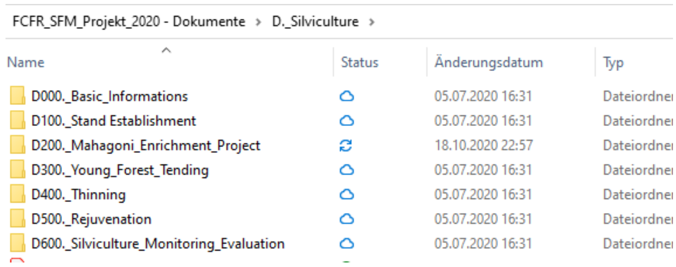


Fig. 13b Data structure second level (example subfolder D._Silviculture)

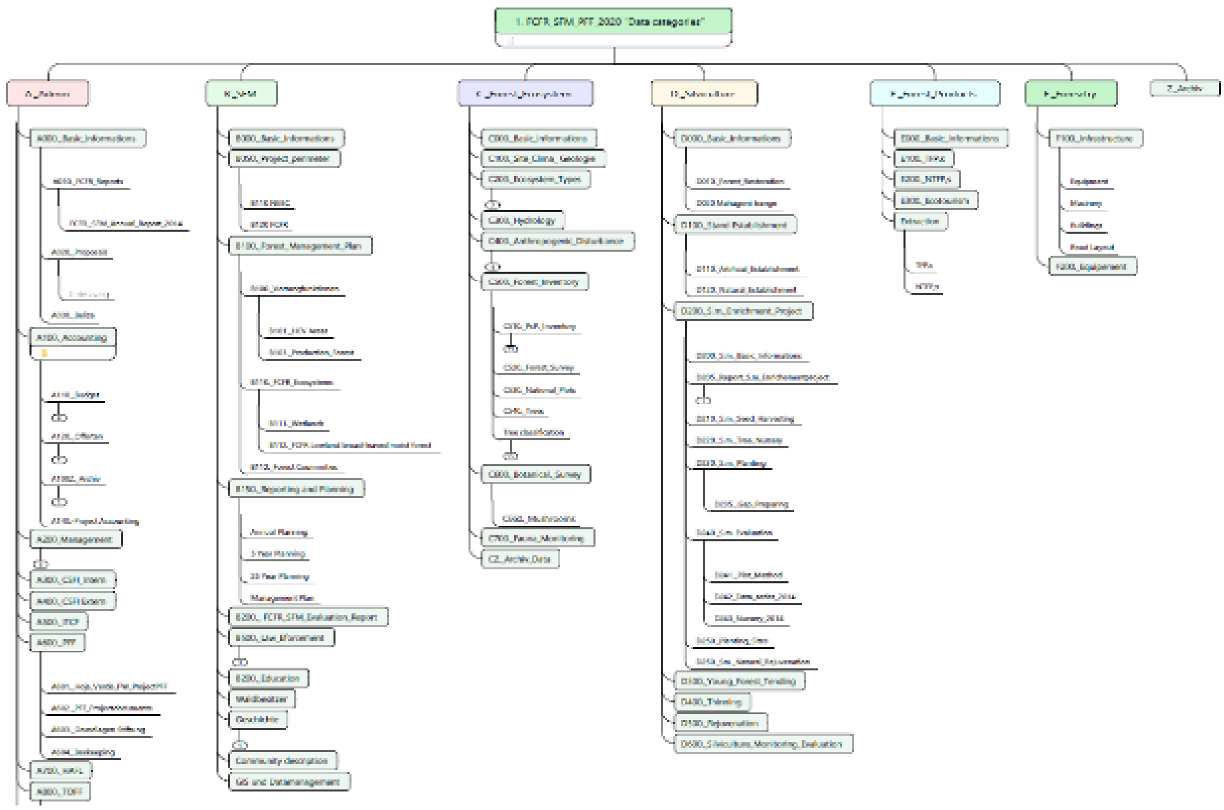


Fig. 13.c Data structure of the FCFR SFM Project and evaluation reports

11 Conclusion

Fig. 11a *Children and youth are the key element for the implementation of the UN SDGs in a given region, especially in view of long-term protection and conservation of ecosystems and protected areas such as the NEBC. However, this requires alternative livelihoods, job opportunities and education.*

Envisioning the true sense of long-term planning is not given to many. Among them, teachers, conservationists and foresters can be found. In the natural world of Belize, a young Mahogany that started growing three hundred years ago in a Belizean forest will have experienced dramatic social and ecological changes over the course of its life. Even today, and providing such a Mahogany tree still existed in Belize today, it would probably need a few more decades to reach a maximum diameter of 3.55 m (as had the largest Mahogany ever felled in the country). Unfortunately, sustainable forest management works on this scale. Possibly not to such great extent, but thinking decades is necessary. The preliminary work that was carried out during the six years of the project thus forms the basis of what is needed to rehabilitate the forests of Freshwater Creek into sustainable, long-term, near-natural production forests. If the basis is now solidly documented, implementing the plan will require a solidly financed second phase.

Before taking that step, we recommend that the baseline data for ecosystem classification and localization be revised and refined with the help of technological developments in remote sensing and spectral analysis combined with terrestrial survey for the NEBC. In order to measure regional and local climate stability would be an advantage, as these data may well be key in evaluating future ecosystems evolution due to climate change, which in turn may influence sustainable forestry management practices.

The CSFI forest inventory program may need to be adapted to new realities in the field, i.e. potential new zonings within the NEBC. The planned combination of a biodiversity monitoring of both flora and fauna together with forestry plot networks should be re-examined. Should the forest inventory program ever be discontinued, we highly recommend that the biodiversity monitoring should not. Synergies as well as cooperation and coordination with FDoB inventory programs and national and international programs or partners should be strengthened and deepened. Existing forest inventory data (2008 and permanent plots), as far as feasible, should continue to be analyzed.

Forestry and conservation have saved local forest ecosystems from conversion into agricultural lands for over 200 years, this particularly through the sustainable use and valorization of natural timber and NTFP resources. This aspect should by all means not be neglected in the future management plan of the SCMA-NEBC system, through a clear definition of and distinction between multiple use areas and strict conservation core zones. Central also in future planning is the securing of an interconnected system of protected areas, ecological stepping stones or elements without anthropogenic influences or interventions. Such a concept should also be implemented in each biome and in every near-natural production forest. All natural resources, be it water or soils, must at all times remain protected and not be impacted by external factors. Furthermore, protected areas and their natural resources can only exist in the long term if they are supported and preserved by the local community. Hence, sustainable, forest-based value chains should be created to provide alternatives to other more destructive economic systems.

If forestry activities are to continue on the long term in the North-eastern Biological Corridor system, it is essential that a professional and well-trained forestry team following the highest standards be created. This will be absolutely key in ensuring long-term success of a SFM project. To achieve this, good policies, governance, management, support and education will be required. Degraded and over-harvested forest will require time and financial resources to be rehabilitated, as much as serious date quality and management.

Finally, in order to be viable on the long-term, a sustainable forest management project within the NEBC should provide benefits to local communities, not only through the creation of much needed employment, but also through a redistribution of profits into local community projects. Local communities and other stakeholder groups should regularly be involved in project developments, and an emphasis should be put on the empowerment of women in all areas.

12 References and relevant documents

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13 Appendix

13.1 Introduction

Following terms used in this document are interpreted according the ITTO Definition

Afforestation	The establishment of a planted forest on non-forested land
Agroforestry	A collective term for land-use systems and technologies in which woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between the different components (Lundgren and Raintree 1982 cited by Nair 1993)
Biodiversity (also "biological diversity")	The variability among living organisms from all sources, including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part: this includes diversity within species, between species, and of ecosystems (Convention on Biological Diversity, Article 2)
Carbon stock / forest carbon stock	The amount of carbon held in the biomass of a given area of forest
Deforestation	The conversion of forest to another land use
Degraded forest	Forest that delivers a reduced supply of goods and environmental services from a given site and maintains only limited biodiversity. Degraded forest has lost the structure, function, species composition and/or productivity normally associated with the natural forest type expected at that site
Degraded forest land	Former forest land severely damaged by the excessive harvesting of wood or non-wood forest products, poor management, repeated fire, grazing or other disturbances or land uses that damage soil and vegetation to a degree that inhibits or severely delays the re-establishment of forest after abandonment
Environmental services	The benefits people obtain from forest ecosystems. They include provisioning services, such as food and water; regulating services, such as the regulation of floods, droughts, land degradation and disease; supporting services, such as soil formation and nutrient cycling; and cultural services, such as recreational, spiritual, religious and other nonmaterial benefits. Forest environmental services perform a range of functions, such as: moderating weather extremes and their impacts; dispersing seeds; mitigating drought and floods; cycling and moving nutrients; protecting stream and river channels and coastal shores from erosion; detoxifying and decomposing wastes; controlling agricultural pests; maintaining biodiversity; generating and preserving soils and renewing their fertility; contributing to climate stability; purifying air and water; and pollinating crops and natural vegetation. Tropical forests provide all these services and are often particularly important for carbon sequestration, biodiversity conservation, the protection of water catchments and the regulation of regional climates
Forest degradation	A reduction in the capacity of a forest to provide goods and environmental services. "Capacity" includes the maintenance of the elasticity of ecosystem structures and functions
Forest governance	The process of governance in a forest area
Forest rehabilitation	A management strategy applied in degraded forest lands that aims to restore the capacity of a forest to produce products and environmental services
Forest restoration	A management strategy applied in degraded forests with the aim of restoring the forest to its pre-degradation state (e.g. in function, structure and species composition)

Forestry	The art and science of managing forests and trees, embracing a broad range of concerns such as the provision of wood and non-timber forest products, biodiversity management, wildlife habitat management, watershed management, water quality management, recreation, landscape protection, erosion control, employment, and carbon sequestration
Governance	The process of determining the way in which society is managed and how the competing priorities and interests of different groups are reconciled. It includes the formal institutions of government but also informal arrangements. Governance is concerned with the processes by which citizens participate in decision-making, how governments are accountable to their citizens, and how society obliges its members to observe its rules and laws (FAO 2009)
Landscape	A cluster of interacting ecosystem types, either pristine or modified by humans
Managed / modified natural forest	Natural forests managed or exploited for wood or non-wood forest products, wildlife or other purposes. The more intensive the use, the more that forest structure and composition is altered compared with primary forests. Ecologically, such alterations often represent shifts to earlier successional stages. Two major categories can be distinguished: managed primary forest, and degraded and secondary forests
Natural forest	Forest composed of native species and in which trees regenerate by self-sown seeds or natural vegetative means
Natural regeneration	Renewal of trees by self-sown seeds or natural vegetative means (Ford-Robinson, cited in Wadsworth 1997)
Non-timber forest products	Goods of biological origin other than timber (i.e. they may include wood fuel) derived from forests, other wooded land and trees outside forests (see categories below)
Permanent forest estate	Land, whether public or private, secured by law and kept under permanent forest cover. This includes land for the production of timber and other forest products, for the protection of soil and water, and for the conservation of biodiversity, as well as land intended to fulfil a combination of these functions. The main categories of the permanent forest estate are protection and production
Primary forest	Forest that has never been subject to human disturbance, or has been so little affected by hunting, gathering and tree-cutting that its natural structure, functions and dynamics have not undergone any changes that exceed the elastic capacity of the ecosystem
Production permanent forest estate	That part of the permanent forest estate assigned to the production of wood and/or to other extractive uses
Protected area	An area of land and/or sea especially dedicated to the protection and maintenance of biodiversity, and of natural and associated cultural resources, and managed through legal or other effective means
Protection permanent forest estate	That part of the permanent forest estate in which the production of wood (and commonly other extractive uses) is prohibited
Resilience	The capacity of a forest ecosystem or landscape to maintain or regain a desired ecological condition following disturbance
Secondary forest	Woody vegetation regrowing on land that was largely cleared of its original forest cover. Secondary forests commonly develop naturally on land abandoned after shifting cultivation, settled agriculture, pasture, and failed tree plantations
Silviculture/silvicultural	Pertaining to the art and science of producing and tending forests by manipulating their establishment, species composition, structure and dynamics to fulfil given management objectives
Sustainable forest management	The process of managing forest to achieve one or more clearly specified objectives of management with regard to the production of a continuous flow of desired forest products and services without undue reduction of its inherent values and future productivity and without undesirable effects on the physical and social environment

Non-timber forest product categories

Non-wood forest product categories

Categories	Material	End use
Animal fodder	Leaves, twigs	Fodder
Fibre	Rattan, bamboo, lianas, cork	Construction, crafts
Foodstuff (animal based)	Bushmeat, wild game, insects, honey, snails, etc.	Food, trophies
Foodstuff (plant based)	Fruits, leaves, vegetables, fungi/ mushrooms, nuts/seeds, berries, roots	Food, oils, drinks, colouring and dye
Gum and sap	Latex, rubbers, gums, resins, chemicals	Chemical raw materials
Medicinal	Medicinal plants and aromatic herbs, spices	Medicine, flavouring, fragrance

13.2 FCFR Ecosystem Types

13.2.1 Tropical evergreen seasonal broad-leaved lowland forest on calcareous soils

	
Name : 23	Tropical evergreen seasonal broadleaf lowland forest over calcareous soils: Yucatan Variant
UNESCO Classification code :	I.A.2.a.{1).(b).K-Y
Altitude	< 50 m
Geology and soil	Calcareous rock close below the surface
Water Regime	Mostly well drained.
Rainfall	Average rainfall less than 1500 mm per year with a pronounced dry season from February through May.
Fire exposure	Limited to areas with slash and burn cultivation.
Description	These are forests in lowland or low hilly areas (to about 200 m) on shallow limestone soils in the north of the country. These forests receive a medium amount of rainfall (J (1200-1500 mm p.a.). They are semi-deciduous and have a canopy height of 15-20 m.
Frequent Plant Species	Characterized by the scarcity of the palms Attalea cohune and Cryosophila stauracantha which are common in similar forests elsewhere in Belize. The predominant tree is the *Chicle* Manilkara zapota. Same other common species include Brosimum alicastrum, Bursera simaruba, Caesalpina gaumeri, Cordia dodecandra, Desmoncus orthaoantbos, Esenbeckia entaphylla, Gymnanfhes lucida, Pouteria campechiana, Sabal mauritiiformis, Sabal yapa, Simarouba glauca, Swartzia cubensis, Swietenia macrophyla , Talisia olivaeforrnis and Vitex gaumeri.
References	Meerman 1993, Bijleveld 1998, Wright et al.: 1, Iremonger and Brokaw 1995,1.2.2.1.1.

13.2.2 Tropical evergreen seasonal broad-leaved lowland swamp forest, tall variant

Legend Code	42
UNESCO Classification code :	I.A.2.g.(1).(a) T
Altitude	< 250 m
Geology and soil	Over calcareous rock.
Water Regime	Ill drained
Rainfall	Average rainfall less than 2000 mm per year with a pronounced dry season from February through May.
Fire exposure	Limited to areas with slash and burn cultivation.
Description	This forest type is low in stature with a broken canopy with a distinctive deciduous element Where the canopy is open there is a distinctive herbaceous layer dominated by sedges sometimes including Scleria bracteata
Frequent Plant Species	Frequently encountered trees include Amyris elemiefra, Bactris spp., Bucida buceras, Calophylum brasiliense, Croton pyramidalis, Croton reflexiflora, Dracaena americana, Metopium brownei, Coccoloba reflexiflora, Coccoloba acapulcensis, Coccoloba cozumelensis, Manilkara zapota, Gliricidia sepium, Ouratea nitida, Sabal mauritiiformis, Simarouba glauca, Swietenia macrophylla and Zygia sp. Thick woody vines are sometimes present. Includes some areas that are locally known "bajos". Haematoxylon campechianum, typically occurs in the wetter, more open sections.
References	Schultze & Whitacre 1999t Wright et at. 1959: 21, 2"1a , 22, Iremonger and Brokaw 1995:

13.2.3 Tropical evergreen seasonal broad-leaved lowland swamp forest, short tree variant

Legend Code	44
UNESCO Classification code :	I.A.2,g.(1}.{a}.
Geology and soil	< 50 m
Water Regime	Mostly over calcium-poor soils. Some hog-wallow micro relief exists.
Rainfall	Average rainfall less than 2500 mm per year with a pronounced dry season from February through May.
Description	Swampy stands of thin stemmed partly deciduous trees and shrubs, without emergents in the Stann Creek district.
Frequent Plant Species	Frequently encountered plants in these forests are Acosmium panamense, Aspidosperma cruenta, Astrocaryum mexicanum, Attalea cohune, Bactris spp., Bucida buceras, Calyptranthes chytraculla, Clidemia sp., Coccoloba·sp., Crysophila stauracantha, Dialium sp., Dracaena americana, Guettarda combsii, Heliconia vaginalis, Hirtella racemosa, Inga sp., Jacquinia paludicola, Miconia sp., Mouriri myrtiloides, Pachira aquatica, Psychotria glomerulata , Psychotria poeppigiana, Scleria bracteata, Swietenia macrophylla Symphonia globulifera, Tabebuia chrysantha, Terminalia amazonia, Viröla sp, Vismia ferruginea, Vochysia hondurensis and Xylopia frutescens. On richer soils Pterocarpus officinalis is found; on poorer soils more Melastomataceae occur, as well as Acoelorraphe wrightii. Where this ecosystem comes close to the coast, Anacardium officinale and Byrsonyma crassifolia can be found.
References	Meerman 1999a, Wright et al. 195 : 14,14a. 14b, 14c; Iremonger and Brokaw·1995: 1.1.1.1.2.1.

13.2.4 Caribbean mangrove forest; mixed mangrove scrub

Composed almost entirely of evergreen sclerophyllous broad-leaved trees and shrubs with either stilt roots or pneumatophores. Epiphytes in general rare, except lichens on the branches and adnate algae on the lower parts of the trees.

	49
Name :	I.A5.b.(1).(c).
UNESCO Classification code :	Mixed mangrove scrub
Altitude	Sea level
Geology and soil	
Water Regime	Not permanently inundated
Rainfall	None
Fire exposure	Mixed mangrove communities.
Description	Mixed mangrove communities
Frequent Plant Species	All three mangrove species occur: Avicennia germinans, Laguncularia racemosa. and Rhizophora mangle. Other frequent species include Acoeloraphe wrightii, Acrostichum aureum, Conocarpus erectus, Eragrostis prolifera , Myrica cerifera and Rhabdadenia biflora

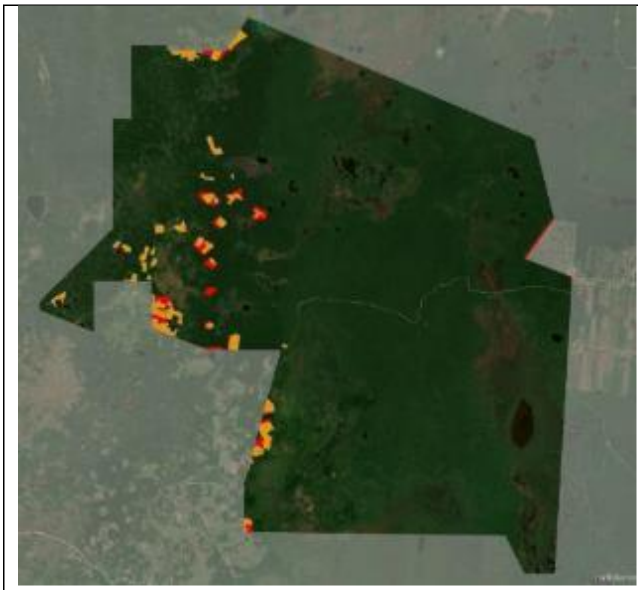
13.2.5 Caribbean mangrove forest; basin mangrove

Legend Code	52??
UNESCO Classification code :	1.A.5„b.(1).(fl.
Altitude	Sea level
Geology and soil	
Water Regime	Mostly waterlogged.
Rainfall	NA
Fire exposure	None
Description	Found along coastal lagoons and in land-locked coastal depression. Species composition and structure in these communities are highly variable depending on frequency and depth of Inundation, nutrient exchange and water salinity levels.
Frequent Plant Species	Rhizophora mangle dorninates in areas which receive frequent tidal flooding or flood waters that are predominantly deeper than 15 cm. Where water depth is less and tidal flushing, amplitude and kinetic energy of floodwaters decrease, other mangrove species and associates invade„ Where salinity reaches levels above 50 o/o Avicennia germinans dominates. In addition to being highly saline the soils may be very reduced (anaerobjc), giving the Avicennia an ecological advantage through its pneumatophores. Where salinity is about 30-40 %, dominant species include Avicennia germinans, Laguncularia racemosa, and Rhizophora mangle. When disturbed the fern Acrostichum aureum becomes the dominant species.
References	Furley & Ratter 1982, Gray et al. 1990, Iremonger and Brokaw 1995: 1. 21. 2.3

13.2.6 Marine salt marsh

Legend Code	66
UNESCO Classification code :	V.E.1.a-.{1}
Altitude	Sea level
Geology and soil	Over calcareous rock.
Water Regime	Partially inundated with brackish water during the rainy season. Salinity increases as water evaporates.
Rainfall	Variable
Fire exposure	Very rare
Description	This community type occurs in marshes in the coastal plains where the salinity level is high, and is generally greater than 5%. This community is highly heterogeneous and containing patches dominated by different species, which are all taken together here to indicate one main salt marsh community type. Good examples occur in the Shipstern Nature Reserve.
Frequent Plant Species	Common dominants in the vegetation are Batis maritima, Distichlis spicata, Fimbristylis spadicea, Fairena sp., Juncus spp., Salicorna perennis, Solanum donianum and Spartina cynosuroides. Flats with these principally herbaceous species may contain stunted Conocarpus erecta and dwarf Rhizophora mangle. Slightly elevated areas in this type of marsh contain forest species such as Bravaisa tubiflora, Metopium browneif, Manilkara zapota and Thrinax radiata. In the Shipstern Nature Reserve, a characteristic plant along small creeks through this ecosystem is Bucida spinosa. These small shrubs are often covered with Tillandsia epiphytes.
References	Davis 1943, Gray et a/. 1990, Meerman 1993, Bijleveld 1998, Iremonger & Brakaw 111.1.2.1

13.2.7 Agriculture



13.3 Forest Inventory

N.m. Bird

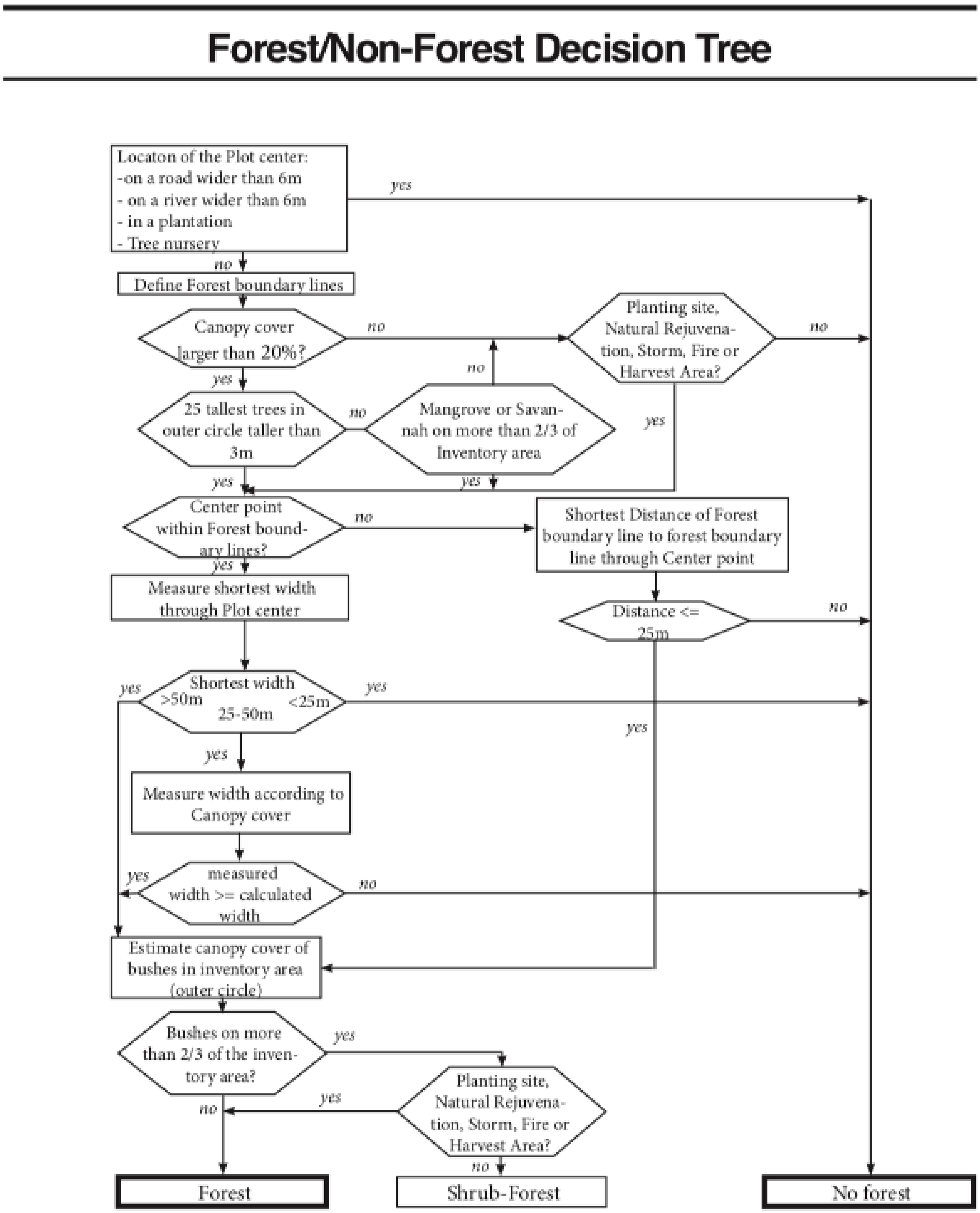
PSP 9

SPECIES	Species code	Number of individuals in stem diameter class (cm)										
		10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	≥100	Total
Pouteria reticulata	124	78	7	0	0	0	0	0	0	0	0	85
Sabal mauritiiformis	101	76	2	0	0	0	0	0	0	0	0	78
Unknown species	103	55	13	0	0	0	0	0	0	0	0	68
Pseudolmedia spuria	64	60	3	0	0	0	0	0	0	0	0	63
PECCARY TREE	391	24	16	9	3	4	1	1	0	0	1	59
Bursera simaruba	15	15	21	10	4	0	0	0	0	0	0	50
Spondias mombin	13	30	16	1	0	0	0	0	0	0	0	47
Dendropanax arboreus	30	23	12	6	2	1	0	0	0	0	0	44
REDWOOD	21	29	12	1	0	0	0	0	0	0	0	42
Protium copal	313	33	3	0	0	0	0	0	0	0	0	36
Metopium brownei	74	17	10	4	2	2	0	0	0	0	0	35
Pouteria durlandii	82	16	13	4	1	0	0	0	0	0	0	34
Alchornea latifolia	37	17	12	1	0	1	0	0	0	0	0	31
Vitex gaumeri	41	15	7	4	0	0	0	0	0	0	0	26
Simarouba glauca	11	13	11	1	0	0	0	0	0	0	0	25
Guazuma ulmifolia	123	10	11	1	0	0	0	0	0	0	0	22
Pouteria sp.	45	12	5	1	1	1	0	0	0	0	0	20
Pouteria amygdalina	320	11	6	1	0	0	0	0	0	0	0	18
Swietenia macrophylla	1	5	5	4	0	0	1	0	0	0	0	15
Brosimum alicastrum	56	2	8	3	2	0	0	0	0	0	0	15
Manikara zapota	73	6	4	0	2	2	0	0	0	1	0	15
Acacia sp.	202	15	0	0	0	0	0	0	0	0	0	15
Lonchocarpus sp.	361	8	6	1	0	0	0	0	0	0	0	15
Astronium graveolens	102	7	5	1	0	0	0	0	0	0	0	13
Guettarda combsii	61	10	1	0	0	0	0	0	0	0	0	11
Cupania belizensis	319	8	0	0	0	0	0	0	0	0	0	8
WILD STAR APPLE	53	6	0	0	0	0	0	0	0	0	0	6
Unknown species	309	5	1	0	0	0	0	0	0	0	0	6
YELLOW MOHO	327	6	0	0	0	0	0	0	0	0	0	6
Zuelania guidonia	109	3	1	0	0	0	0	0	0	0	0	4
Nectandra sp.	147	4	0	0	0	0	0	0	0	0	0	4
WILD IZOTE	345	4	0	0	0	0	0	0	0	0	0	4
Bernoullia flammea	6	0	2	0	1	0	0	0	0	0	0	3
Annona reticulata	121	3	0	0	0	0	0	0	0	0	0	3
Cymbopetalum mayanum	187	3	0	1	0	0	0	0	0	0	0	4
WILD CHERRY	384	3	0	0	0	0	0	0	0	0	0	3
Guarea sp.	70	2	0	0	0	0	0	0	0	0	0	2
Lonchocarpus castilloi	76	2	0	0	0	0	0	0	0	0	0	2
Swartzia cubensis	84	0	1	1	0	0	0	0	0	0	0	2
Sideroxylon floribundum	196	1	1	0	0	0	0	0	0	0	0	2
Ormosia sp.	314	0	1	1	0	0	0	0	0	0	0	2
WHITE KENEP	318	0	2	0	0	0	0	0	0	0	0	2
Clusiaceae sp.	352	1	1	0	0	0	0	0	0	0	0	2
Tabebuia chrysantha	44	1	0	0	0	0	0	0	0	0	0	1
WILD GUAVA	62	1	0	0	0	0	0	0	0	0	0	1
FUSTIC	87	1	0	0	0	0	0	0	0	0	0	1
Zanthoxylum sp.	127	1	0	0	0	0	0	0	0	0	0	1
Heliocarpus americanus	311	1	0	0	0	0	0	0	0	0	0	1
Pseudobombax ellipticum	315	1	0	0	0	0	0	0	0	0	0	1
CORN TREE	337	1	0	0	0	0	0	0	0	0	0	1
	Total	645	219	56	18	11	2	1	0	1	1	954

PSP 10

SPECIES	Species code	Number of individuals in stem diameter class (cm) 10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	≥ 100	Total
Sabal mauritiiformis	101	64	1	0	0	0	0	0	0	0	0	65
Pseudolmedia spuria	64	53	9	0	0	0	0	0	0	0	0	62
Bursera simaruba	15	19	30	8	2	0	0	0	0	0	0	59
Pouteria durlandii	82	38	14	3	2	0	0	0	0	0	0	57
Pouteria reticulata	124	51	5	0	0	0	0	0	0	0	0	56
Lonchocarpus castilloi	76	26	17	9	1	0	0	0	0	0	0	53
Unknown species	103	37	8	1	0	0	0	0	0	0	0	46
Spondias mombin	13	28	14	1	0	0	0	0	0	0	0	43
Simarouba glauca	11	22	16	3	0	0	0	0	0	0	0	41
REDWOOD	21	21	13	0	0	0	0	0	0	0	0	34
Acacia sp.	202	32	0	0	0	0	0	0	0	0	0	32
Protium copal	313	28	4	0	0	0	0	0	0	0	0	32
PECCARY TREE	391	12	11	6	0	0	0	2	0	0	0	31
Dendropanax arboreus	30	12	10	3	4	0	0	0	0	0	0	29
Guettarda combsii	61	21	6	0	0	0	0	0	0	0	0	27
Pouteria amygdalina	320	13	11	2	0	0	0	0	0	0	0	26
Metopium brownei	74	12	10	1	2	0	0	0	0	0	0	25
Alchornea latifolia	37	18	5	1	0	0	0	0	0	0	0	24
Brosimum alicastrum	56	9	10	3	1	0	0	0	0	0	0	23
Astronium graveolens	102	18	3	1	0	0	0	0	0	0	0	22
Cupania belizensis	319	21	0	0	0	0	0	0	0	0	0	21
Manilkara zapota	73	14	3	1	1	0	0	0	1	0	0	20
WILD CHERRY	384	18	1	0	0	0	0	0	0	0	0	19
Vitex gaumeri	41	7	6	0	0	0	0	0	0	0	0	13
Swietenia macrophylla	1	1	5	6	0	0	0	0	0	0	0	12
Pouteria sp.	45	4	3	5	0	0	0	0	0	0	0	12
Nectandra sp.	28	5	3	0	0	0	0	0	0	0	0	8
Guazuma ulmifolia	123	5	3	0	0	0	0	0	0	0	0	8
WHITE KENEP	318	2	3	2	0	0	0	0	0	0	0	7
Bernoullia flammea	6	0	2	2	1	0	0	0	0	0	0	5
Guarea sp.	70	5	0	0	0	0	0	0	0	0	0	5
Swartzia cubensis	84	2	1	1	1	0	0	0	0	0	0	5
Clusiaceae sp.	352	4	0	0	1	0	0	0	0	0	0	5
Stemmadenia donell-smithii	66	4	0	0	0	0	0	0	0	0	0	4
Unknown species	309	2	2	0	0	0	0	0	0	0	0	4
QUIEBRA ACHA	387	2	2	0	0	0	0	0	0	0	0	4
WILD STAR APPLE	53	3	0	0	0	0	0	0	0	0	0	3
Annona reticulata	121	3	0	0	0	0	0	0	0	0	0	3
Sideroxylon floribundum	196	3	0	0	0	0	0	0	0	0	0	3
YELLOW MOHO	327	3	0	0	0	0	0	0	0	0	0	3
Tabebuia chrysantha	44	2	0	0	0	0	0	0	0	0	0	2
Calophyllum brasiliense	46	1	1	0	0	0	0	0	0	0	0	2
Trophis racemosa	55	2	0	0	0	0	0	0	0	0	0	2
WILD GUAVA	62	2	0	0	0	0	0	0	0	0	0	2
COPAL	108	2	0	0	0	0	0	0	0	0	0	2
Zuelania guidonia	109	0	1	1	0	0	0	0	0	0	0	2
WILD IZOTE	345	2	0	0	0	0	0	0	0	0	0	2
Lonchocarpus sp.	361	2	0	0	0	0	0	0	0	0	0	2
Unknown species	54	1	0	0	0	0	0	0	0	0	0	1
Licaria sp.	167	1	0	0	0	0	0	0	0	0	0	1
Cymbopetalum mayanum	187	1	0	0	0	0	0	0	0	0	0	1
WILD COFFEE	368	1	0	0	0	0	0	0	0	0	0	1
Cordia dodecandra	393	1	0	0	0	0	0	0	0	0	0	1
	Total	660	233	60	16	0	0	2	1	0	0	972

13.3.1 Forest non forest decision tree



13.3.2 Belizean SFM Chronology

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, Howell1994, Hummel 1925, Humphreys 1981 , Krohn 1987, Mell 1930-32, Melville 1936, Metzgen and Cain 1925, Smith 1991 ,Stevenson 1933, Ussach 1992).

13.3.3 Historical SFM notes within FCFR

The following brief descriptions by topic of major forest management activities and experimental observations on Mahogany in FCFR 1924 through the mid- 1960's (P.L. Weaver and O.A. Sabido, 1997).

Hurricanes:

- *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 year after the 1942 storm; those in an adjacent pasture contain numerous capsules. Diameter growth also varies: trees in the forest average 0,3 cm / year, whereas those in the pasture average 1.2 cm per year (Lamb 1949).*
- *Mahogany trees in natural Forest do not show an increase in diameter growth until 4 Years after the 1942 hurricane (Lamb 1947a)*
- *The post-hurricane restriction of felling to dead and damaged Mahogany trees on 4 ha of good pre-hurricane Mahogany forest yields an average regeneration of 26 trees / ha under 4,5 m tall; results: justify the policy of restriction fellings of undamaged Mahogany until adequate regeneration is attained (Lamb 1949)*

Seedling Improvement and Regeneration

- *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 25.6 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)*

Plantations (mainly Taungya)

- *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)*

Release, Thinning, and Pruning

- *Girdling inferior species and cutting vines result in greater Mahogany leafgrowth, 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)*