CSFI COROZAL SUSTAINABLE FUTURE INITIATIVE

Sustainable Forest Management at Freshwater Creek Forest Reserve

Principles and background information

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Abbreviations

CSFI	Corozal Sustainable Future Initiative
DBH	Diameter at breast height (1.3m)
DCH	Diameter at crown height
FCFR	Freshwater Creek Forest Reserve
FD	Belizean Forestry Department
FSC	Forest Stewardship Council
HCV	High Conservation Value
NRP	Natural Reproduction
NTFP	Non-timber forest products
PP	Permanent Plot
RBCMA	Rio Bravo Conservation and Management Area
REDD+	Reduced Emissions from Deforestation and Forest Degradation - plus

Summary

Freshwater Creek Forest Reserve (hereafter FCFR) in northeastern Belize covers an area of approximately 130 km^2. Following preliminary studies in 2014, 4'654ha or 35% of the total area of FCFR was designated as production forests. The remaining 65% are classified mostly as strict conservation zone and, for a smaller part, as forests that at present are too difficult to reach. CSFI's strategy aims at gradually being able to manage 185ha annually, first in order to rehabilitate depleted forests, and later as the annual harvest area within a 25 years harvesting cycle.

In order to develop a forest management strategy and provide a solid basis for decision makers, the following aspects need to be looked at in detail:

1. Which are the local commercial timber species and what are their market prices?
2. How much is the annual volume increase and stock of trees in FCFR?
3. What are the species' diameter and geographic distribution of trees in FCFR?
4. Is the remaining harvesting potential high enough to start commercial logging activities?
5. What are the mortality rate and annual height increase of replanted Mahoganies and other hardwoods?

In 1993, the Government of Belize / Forest Department installed two permanent plots, which were measured again in 2015. Based on these data, a rough estimate of volume increase and present stock concluded that within 25 years, volume increase is around 35 m^3 per hectare, while stock lies around 116m^3.

Methodology of stock survey has been further developed to classify trees into future trees, seed trees, habitat trees and harvestable trees, respectively. A total of 53ha has been surveyed, gathering data from all over the reserve. As expected, most valuable timber wood species have been extracted from the area in the past. The average income potential per hectare is estimated at 87US$. Extrapolated to the whole area, annual revenue would be around 16'000US$. This number is far below the operational costs to harvest this area. Fortunately, the ecological value of the reserve remains intact, at least functionally.

One year after the initial test-planting in 2014, all seedlings were re-measured. From the 1036 planted trees, 531 are still alive (mortality rate of 41.5%). Average increase was 34cm in one year. Mortality rate of natural re-growth was 2.4%, significantly lower than in the case of planted trees. Surprisingly, with only 14.8cm, their growth was also significantly lower.

To ensure both a maximum growth of target species and an increase in the number of high value timber trees, the following management activities will have priority during the next 25 years:

1. (Pre-)commercial thinning;

2. Clearing of gaps and planting of *Swietenia macrophylla* (Mahogany), and possibly other hardwood species.

Over the course of our initial studies, around 20 timber species have been identified. On the local market, an average unit price of 222 US$/$m^3$ can be fetched. 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 needs to be developed to profit from other, less valuable tree species and wood waste. All these factors can multiply the present value of production forests within FCFR and consequently may significantly influence the profitability of harvesting activities.

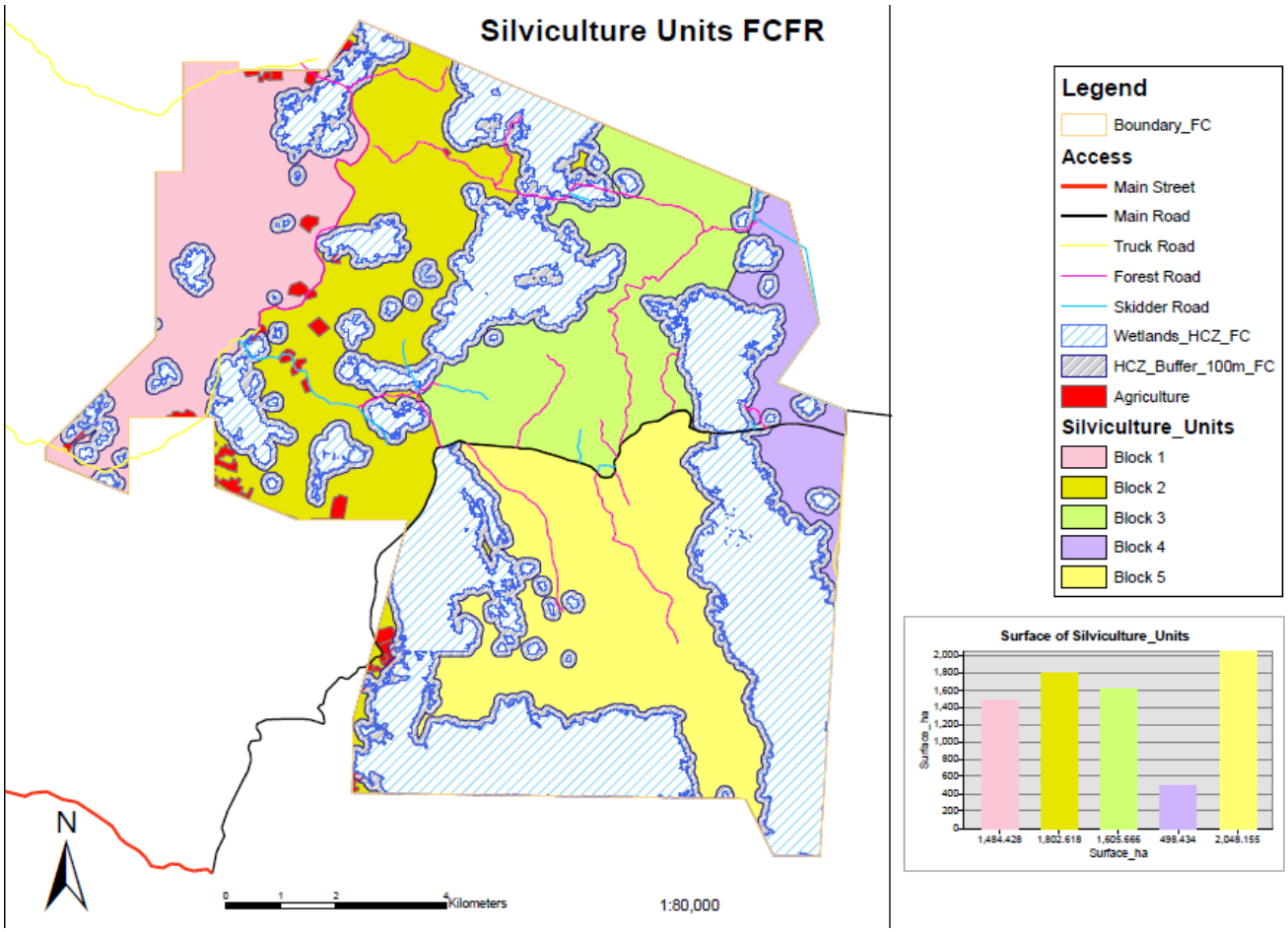

Figure 1: Overview over Freshwater Creek Forest Reserve.

1. Introduction

1.1 Background

In 2013, the Corozal Sustainable Future Initiative (CSFI) signed a concession agreement with the Government of Belize for the management of Freshwater Creek Forest Reserve (FCFR). That same year, CSFI implemented mostly urgent measures to secure the area and make sure illegal activities stopped. In 2014, however, four main activities were started. At first, a general map of the area was created defining High Conservation Value zones (HCVs), as wells a future forest management areas. Next, four different forest inventory methodologies were implemented in order to gather a maximum of information on today's state of the forests in FCFR. Thirdly, seeds of *Swietenia macrophylla* (Mahogany) and *Cedrela mexicana* (Cedar) were collected, and various planting methods were scientifically tested, while around 10'000 seedlings were produced and analyzed. Last but not least, more than 1000 trees were planted and documented to evaluate the success of reforestation. These activities helped to increase knowledge about FCFR significantly and serve as a solid background to further develop forest management activities. The task for 2015 was to define a sustainable forest management plan, based on conclusions reached in 2014.

1.2 Forest area

The total area of FCFR is approximately 130 km^2. In 2014, 56% of the total area of FCFR was classified as strict conservation zone (which includes 20% of forest area) (fig. 1). Inside these zones, no forestry operations other than seed collection are allowed. The remaining 44% of the area (14,250 acres or 5,850 ha) have been designated as "production forests" (CSFI 2014).

As some parts of the area are difficult to access, it was decided that during an initial phase, one would focus on a 500m-buffer around existing roads. As the road network has not yet been completely mapped, this buffer area may slightly increase in the future. Presently, the total production forest area is 4'654 ha or 35% of the total area of FCFR (fig. 2). As a consequence, strict conservation forests increase from 20% to 29%. This situation should be reanalyzed after a first cutting cycle, when accessibility and knowledge of the area have improved.

For most hardwood species, a 25-year cutting cycle is usually applied. Extrapolated on the total area of production forests, 185ha can or should be worked on, first for rehabilitation and subsequently for harvesting.

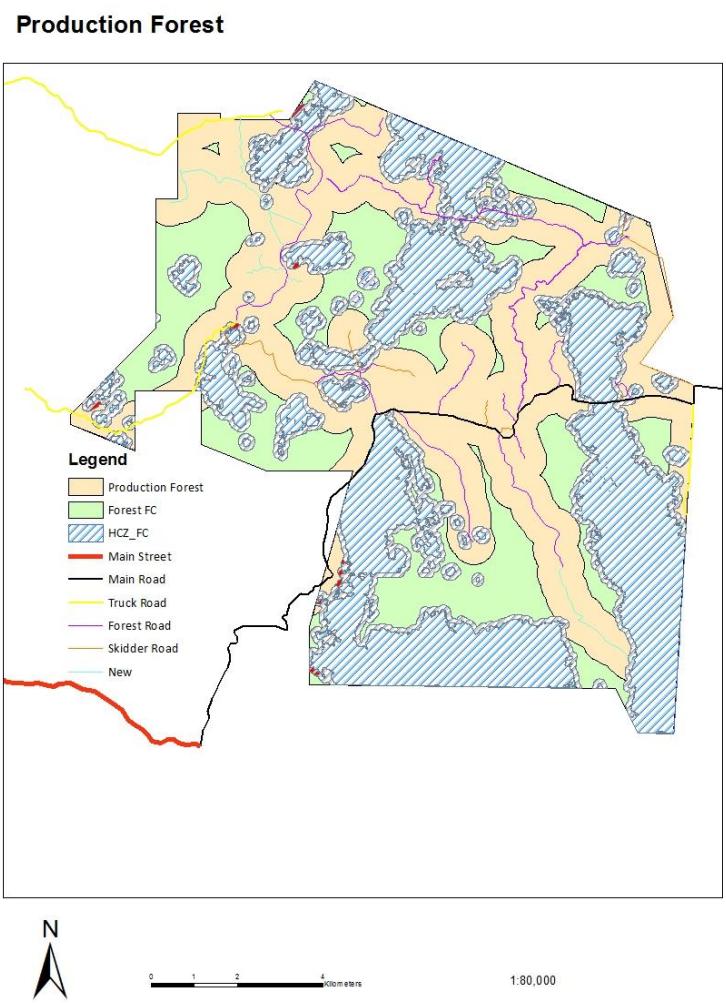

Figure 2: A 500m buffer around the existing roads was desgnated as production forest.

1.3 Stock survey 2014

In 2014, nine hectares were surveyed, applying various forest inventory methods. In most of the plots, a stock survey was carried out, with only trees of economic or ecological interest measured. Since knowledge about valuable timber species was low, several species of low economic interest were recorded. A total of 827 trees with a DBH larger than 20cm was measured and - when possible - identified. Table 1 gives an overview of the various survey plots. No survey was carried out in blocks two, four and five. Six of the plots are located in block 3 and contiguous.

Table 1: Summery of the findings from the stock survey 2014.

Block	Trees per Plot	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**

Tree quality was categorized as follows: bad, fair/nice, good, special, habitat. No description of the categories is available. From the comments, it can be supposed that "special" refers to habitat either than to especially good timber wood.

Table 2: Number of identified species in the stock survey 2014.

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

25 different tree species were identified (table 2). The most abundant tree species was *Simarouba glauca* (Negrito, 80), followed by *Bursera Simaruba* (Red Gumbolimbo, 60) and *Calophylum brasiliense* (Santa Maria, 60). Santa Maria and *Metopium brownei* (Black Poisonwood / Chechem, 55) are two interesting timber species that are clearly abundant. There is also a high number of *Manilkara zapota* (Sapodilla, 45) and *Lonchocarpus castilloi* ((black) Cabbage Bark / Machich, 28), which are two other

timber species of local interest. A challenge to address is the identification of the 227 specimens, i.e. about one quarter of all measured trees. A low amount of *Swietenia macrophylla* (Mahogany / Caoba, 14) was recorded.

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. Low valuable timber species (*Caesalpinia gaumeri* (Warree wood), *Bombax ellipticum* (Mapola)) are dominating but there are still some *Manilkara zapota* (Sapodilla, 6), *Metopium brownei* (Black Poisonwood 1) and *Swartzia spp.* (Bastard Rosewood 1) left. Nevertheless, most trees have a DBH smaller than 40cm (78%), of which 42% have a DBH below 30cm (fig. 3).

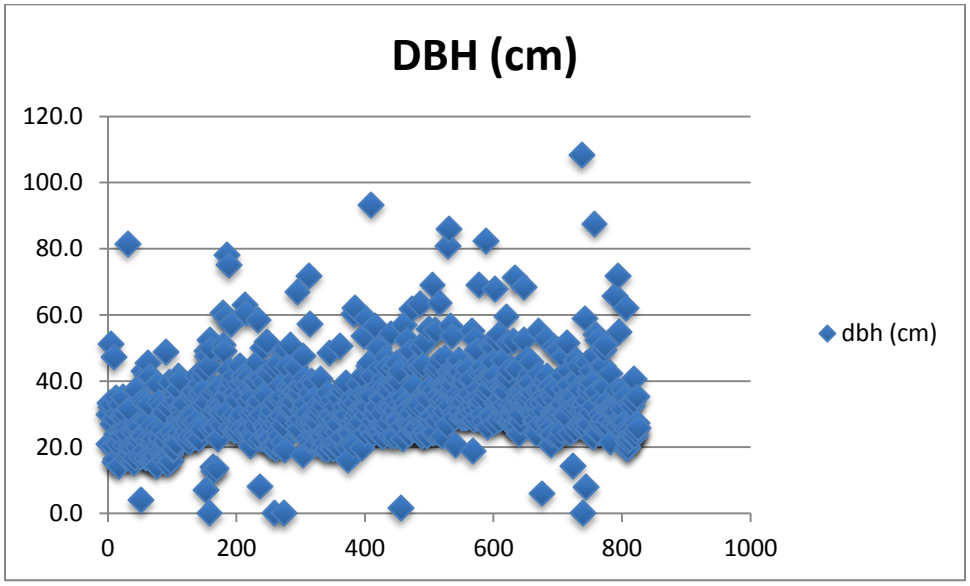

Figure 3: DBH distribution of all 827 trees recorded in the nine hectares.

1.4 Organization, planning, working conditions

The Corozal Sustainable Future Initiative (CSFI) has been confronted with much extra work and new tasks after having been granted the concession for FCFR. 2014 was a challenging year, during which staff often put in long hours, since forestry work grafted itself on many other regular surveillance and maintenance duties.

In parallel, CSFI has expanded significantly within the last few years. The number of employees increased from five to 16. Additionally, number of visitors and therefore tourism activities strongly increased in the first semester of 2015. Obviously, these factors led to challenges concerning organization, communication and planning. Therefore, the definition of decision processes, responsibilities and precise tasks becomes even more important.

It is thus quite clear that forestry operations cannot, in future, be carried out by CSFI's regular staff, and that should forestry operations be implemented as planned, a separate CSFI forestry team needs to be established and financed.

Within this context, priorities as to which activities to implement were set for the first semester of 2015. Not all activities started in 2014 could be continued with the same intensity. Maps were not further developed and no new trees were planted. One permanent plot (PP), however was re-measured. Priority was given to stock surveys in areas where no information about forest composition was

available. Additionally, trees planted in 2014 had to be re-measured to garner first knowledge about growth conditions.

In order to develop a forest management strategy and provide a solid basis for decision makers, the following aspects need to be looked at in detail:

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Units

In general, Belize applies US customary/Imperial units. An exemption is the research activities conducted in the SI units. Therefore, lots of transformations are needed. The table below shows some of the most important transformation values.

fbm	*board foot*	*0.002360 m^3*	*1⁄12 ft^3*
in	*inch*	*0.0254 m*	*1/12 ft*
ft	*foot*	*0.3048 m*	*12 in*
ft^3	*cubic foot*	*0.0283 m^3*	*12 fbm*
m	*meter*	*3.28 ft*	*39.37 in*
m3	*cubic meter*	*423.776 fbm*	*35.3 ft^3*
Bz$/fbm	*Belize dollar per board foot*	*211.86 US$/$m^3$*	
US$/m3	*US dollar per cubic meter*	*0.00472 Bz$/fbm*	

Figure 4: Units transformation values.

2 Potential Timber species

2.1 Introduction

Understanding of local and international timber markets is fundamental to define forest management activities. Key species and valuable timber species have to be identified and recognized before starting stock surveys, in order to be able to increase their number, their DBH and their quality on the long term. CSFI at present possesses only limited Knowledge of timber markets, especially at the international level, and no commercial relations with the local lumber trade exists. Such knowledge about the timber prices is nevertheless vital if one is to estimate or extrapolate the value of timber within forests.

2.2 Methods

To gather information about timber prices, three different methods were applied: internet research, informal interviews with experts from the Belize Forest Department (FD), and finally, local sawmills were visited and their owner interviewed.

2.3 Results

Very little information about local timber markets is readily available, and certainly not online. However, several local saw mills were identified and contacted to obtain further information. As to current prices for round wood on the regional / international markets, no relevant information was found. Findings about lumber prices were furthermore difficult to compare, since prices vary according to size and quality, two in our case and as yet unknown data. Additionally, the existence of specific trade names for the various tree species in the area makes comparison very challenging. However, several wood trade platforms have been discovered on which Belizean lumber was sold, and these may prove, in due course, to be potential channels of distribution, once harvesting and further processing starts. One list was published by Balam Jungle (2004), an area close to FCFR (table 3), which had boards 5ft and longer and with 1 or 2 inches thickness on offer.

Table 3: Pricelist for lumber published by Balam Jungle in 2004.

Latin Name	English Name	International Price [USD/m^3]	Local Price [USD/m3]
Cordia dodecandra	Ziricote, Zericote	2542.38	-
Cedrela Mexicana	Spanish Cedar	2118.65	487
Swartzia cubensis	Bastard Rosewood	2012.7175	222
Metopium brownie	Black Poisonwood	2012.7175	222
Platymiscium yucatanum	Granadillo	1800.8525	222
Cordia alliodora	Salmwood	1800.8525	222
Swietenia macrophylla	Big leave Mahogany	1377.1225	487
Lonchocarpus castilloi	Cabbage Bark (black)	1165.2575	222
Aspidosperma megalocarpon	Mylady white	1080.5115	222
Bucida buceras	Bullet Tree	1038.1385	222
Manilkara zapota	Sapodilla	953.3925	222
Dendropanax arboreus	White gumbolimbo	953.3925	170
Calophylum brasilense	Santa Maria	911.0195	222

In January 2015, an interview with Mr. Lewis Usher of the Belize Forest Department revealed that seven timber species of hardwoods are of special economical interest (see table 4 below).

Table 4: High price timber species

Latin	English	Local	min DBH [cm]	Abundancy [Nr/ha]
Swietenia macrophylla	Big leave Mahogany	Caoba	65	1.5
Metopium brownie	Black Poisonwood	Chechem	50	6
Platymiscium yucatanum		Granadillo	45	Low
Astronium graveolens		Hobillo	none	Low
Dalbergia stevensonii	Rosewood	Rosewood	none	none
Cordia dodecandra		Ziricote, Zericote	none	low
Cedrela Mexicana	Cedar	Cedro	65	low

In March 2015, Dr. Cho of the FD confirmed the high economic importance of these species, and mentioned that they were indeed exported as round wood since no high quality sawmill is present in Belize. He estimated a price of around 6 Bz$fbm^{-1} (1270 US$m^{-3}) on the international market, which is about three to six times higher than the local prices (table 5). He compared the value of *Swartzia spp.* with that of *Astronium graveolens* and *Lonchocarpus castilloi*, indicating however that *Astronium graveolens* is not within the high price range. Some other species may belong to the high price category.

Table 5: Overview of the prices on the local and international market 2015

Segment	Price [Bz$fbm^{-1}]	Price [US$m^{-3}]
International	6	1270
high price	2.3	487
medium price	1.1 / *1.05	233 / *222
*low price	0.8	169
**sawn lumber	1.5	317

*only when assuming sawmill is at FCFR
**indicative price for species for species fetching medium prices

To improve knowledge on local timber market, 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$fbm^{-1} (487 US$m^{-3})) and a second price for all other tree species (1.1 Bz$fbm^{-1} (233 US$m^{-3})). He does not buy *Metopium brownei* (Black Poisonwood) because it affects the health of his employees. He has a three-year contract with Rio Bravo Conservation and Management Area (RBCMA), which is FSC certified. However, he also buys non-certified wood, while purchasing all timber species listed in table 6, with the exception of *Dendropanax arboreus* (White Gumbolimbo). His facility runs on electric power.

In Newland - very close and to the East of FCFR - another less developed sawmill is found, running with the help of an old truck's engine. Wood waste is burnt right behind the facility. 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}).

Table 6: Tree species of medium economic interest

Latin	English	Local	min DBH [cm]	Price [US$/m^3]
Lonchocarpus castilloi	Cabbage Bark (black)	Machich	60	222
Pouteria mammosa	-	Mammey		222
Etythroxylon aerclatum / 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

2.4 Conclusions

There are about twenty different tree species of economical interest. Little information about timber prices is available online. 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 fuel wood is actually sold on the market.

The installation of a high quality saw mill in Belize is of major importance if one is to increase the value of wood 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 make use of other, less valuable tree species as well as wood waste. All these factors could multiply the present value of the Freshwater Creek FR and influence the profitability of future harvesting activities.

Surprisingly, both sawmills will not buy *Metopium brownei.* The high price for Black Poisonwood can only be achieved with trees of 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's are therefore highly required to ensure the selection of the right trees. Experimenting with the production of seedlings and plantations of this species would be desirable.

Knowledge about local and international markets, timber prices and wood products still needs to be improved. A person with experience in the field of tropical hardwood trade is needed to help explain standards in lumber size and species knowledge at an international level. The price list for local and international markets, as given in this report, still needs to be further improved and adapted as knowledge increases.

3 Volume Increase and Stock

3.1 Introduction

Volume increase and stock are two fundamentals necessary to draw conclusions about forest potential. Consequently, any decision about sustainable forest management activities will have to consider the increment of growth and the present timber volume. For FCFR, this information is unfortunately not available. A quick online research also did not reveal any useful data. Fortunately, last year's efforts to re-measure the governmental Permanent Plot did offer some valuable data, and the only opportunity to gather information about volume increase. From the data, stem volumes were extrapolated (DBH to crown base without branches), and volumes thus obtained do not equal total tree biomass (for e.g. carbon stock calculations).

3.2 Methods

The Permanent Plot (PP) was established by the Belizean Forest Department and initially measured in 1993 (NE-Point PP9: 1996386/358791; SE-Point PP10: 1996466/358795). The first re-measurement was conducted 22 years later in 2015. With regard to volume estimates presented in table 8, all trees with at least one of the following attributes were excluded: trees with a diameter at breast height (DBH)<10cm, Dead Tree (DT), Alive fallen (AF), Alive partially rotten (AR, RT), Alive with strangler fig (AS), Broken top (BC, BT), Leaning tree and/or supported by other trees (LT), Near death, declining (ND), vanished (v). A total of 578 trees were included.

Tarif-volume estimation of trees is challenging, since most trees do not have a regular geometric form. In the absence of local equations, cubic volume of wood for standing trees may be estimated by the following equation:

$V=0.42 * B * H$,

where B is tree basal area at breast height ($DBH^2*\pi/4$) and H is tree merchantable height (FAO 25.3.2015). DBH and height have to be converted into meters. Nevertheless, several other equations were applied to get a better idea of the sensitivity (Table 8).

For the income estimate, two additional volume calculations have to be introduced (table 7): on the one hand, the volume upon which FD royalties are calculated and second, the volume calculated by the sawmills defining the price they will offer.

Table 7: Relevant volume formulas

Volume Definition	Formula	Explanation	Source
Stem Volume (m^3)	V=B*H*0.42	Calculated from the DBH (m) and multiplied with a coefficient (f_1=0.42)	FAO (25.3.2015)
Royalty Volume (fbm)	V=((DBH+DCH)/2)^2*H*0.034	Square of the average from the diameters (in) at both ends multiplied with H (ft) and a coefficient (f_2=0.034)	FD Orange Walk
SM Volume (fbm)	V=DCH^2*H*0.034	Square of the DCH (inches) multiplied with H (feet) and a coefficient (f_2=0.034)	Saw Mill Owner Newland

3.3 Results

As expected, formulas assuming a cylindrical volume are in general overestimating the volume. In comparison, Vf0.33 is underestimating the volume, as trunk shape is not a cone. The results show that applying a 25-year cutting cycle approximately 35m^3 per ha can be harvested. Only a part of this amount represents timber value of local interest. Table 9 gives an overview over the diameter and volume increase of timber-species found on the PP.

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

A total of 7.9 m^3 of timber trees could in theory be harvested on the Permanent Plot. A closer examination of the trees reveals that only two of them are actually worth extracting, as most trees have a smaller diameter, below 40cm. These two trees together have a stem volume of around 1.6m^3.

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^3yr^{-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)

3.4 Conclusions

At present only little information about growth increments exists. Although the re-measurement of a Permanent Plot allows for a rough estimate, it may not represent the whole area. The evaluation of the second permanent plot nearby should further improve knowledge on volume increase and stock within the area. Nevertheless, it is recommended to gather more data to confirm these estimates.

Although, Vf0.42 gives a good first idea it is suggested to further improve volume estimating equations. Measuring of diameter from logged trees every meter to calculate the real volume is recommend. Out of these data, tables or formulas can be concluded. Dr. Cho of the FD mentioned that there is a volume equation for forests in Belize, which may possibly allow for a better approximation.

Knowledge about diameter increase for 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 by applying various silvicultural techniques.

4 Forest inventory 2015

4.1 Introduction

Tree inventories are important to improve knowledge about forest conditions. To get a precise overview over a large area ties considerable resources. It is challenging to find an appropriate inventory technique to gather information at low to medium costs. In 2014, CSFI staff was trained in four different inventory techniques. Out of these, stock survey was found as the most appropriate one to increase knowledge about species composition, tree quality and DBH distribution, respectively.

4.2 Methods

In 2015, two different inventory techniques were applied. First, the FD permanent plot (a one hectare area divided into 25 subplots of 20m to 20m) was re-measured. Every tree with a DBH>10cm was measured. The following attributes were documented: Tree species, DBH, height, crown height, DCH and different aspects of crown and tree growth, respectively. In the central subplot every single woody plant with a DBH>1cm was measured. The method was adopted from Rainfor 2009 and a detailed description of the method is available at the Forest Department.

Second, stock survey was carried out, while expanding the technique in order to make the surveyed hectares ready for (pre-) commercial thinning. To increase knowledge about forest conditions within FCFR, several areas in block two and five were surveyed (fig. 4). This methodology was adopted whenever conditions permitted. In two hectares, every tree with a DBH>20cm was measured, but since this method was very time consuming, it was decided to focus mainly on the timber species (table 4 and 6). The trees were classified depending on their quality, DBH and species.

The following categories were introduced:

- Future Tree (FT): Tree species listed in table 6 with fair or good quality;
- Seed Tree (ST): Tree species listed in table 4 or species listed in table 6 with bad quality;
- Habitat Tree (HT): Tree species with ecological importance (e.g. fruit, holes etc.)
- Harvest next year (HNY): Competition trees from FT or ST or tree species listed in table 6 with a DBH>min DBH.

Due to their ecological importance, all specimens of *Pouteria mammosa*, *Manilkara zapota* and *M.(Achras) chicle* were classified as habitat trees.

A detailed description of the methodology can be found in annex 10.4.

4.3 Results

The data from the PP and the first two hectares of the stock survey enable us to draw conclusions about forest conditions, as every tree (DBH>20cm) was measured. The average DBH in these plots is between 26.9 and 29.6cm. Around 300 trees can be found in a one hectare unit (table 10). *Bursera Simaruba* (Red Gumbolimbo), *Spondias mombin* (Hogplum) and *Dendropanax arboreus* (White Gumbolimbo) are among the most abundant species. *Metopium brownei* (Black Poisonwood) and Machich (*Andira Inermis* & *Lonchocarpus castilloi*) are the most abundant of the valuable timber species (table 11).

Table 10: Overview over the three hectares, where every single tree with a DBH>20cm was recorded.

Ha Name	369	370	PP
Area	San Juan	San Juan	Milla 7
Nr. Of trees with DBH>20cm	259	310	334
Nr. of species	30	33	34
Nr. Of timber trees	37	39	71
Average DBH [cm]	27.5	26.9	29.6

Table 11: Species composition of three different hectares at FCFR.

Ha Name	369	370	PP
Bastard Rosewood	3	6	1
Bay Cedar	5	1	11
Black Poisonwood	8	5	20
Botan Wano	23	10	1
Breadnut	3	10	10
Caimito	3	1	0
Copal	12	4	6
Cortez	0	0	1
Fiddlewood	19	13	10
Glassywood	6	5	3
Hobillo	0	0	6
Hogplum	40	26	13
Huevo de Perro	1	0	0
Jack Pom	0	1	0
John Crow Bead	0	0	1
Katal'ox	8	2	0
Machich	11	11	9
Madre Cacao	2	0	0
Mahogany	2	3	2
Malerio	0	1	0
Mamey	1	3	0
Mamey cerilla	0	3	19
Mapola	2	3	3
Negrito	11	16	11
Qiebra hacha	0	1	0
Red Gumbolimbo	33	46	37
Red Sillion	2	4	21
Redwood	0	0	12
Roble	0	0	4
Santa Maria	2	7	0
Sapodilla	0	0	8
Sapote Macho	0	4	0
Sapotillo	1	15	12
Strangler Fig	1	2	2
Tapa Culo	0	1	0
Tempiste	0	0	1
Waree wood	12	1	29
Water wood	1	0	1
White Gumbolimbo	11	23	21
Wild Cherry	3	15	10
Wild Grape	8	10	4
Wild Kenep	19	10	1
Wild Sursop	0	0	1
Ziricote	1	0	0

Stock survey was carried out in a total of 53 hectares and 1778 trees were recorded. Table 12 gives an overview of trees measured in each area of the reserve.

Table 12: Summery of the results from the stock survey

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]	Income per plot [USD]
San Juan	10	604	60.4	30.2	7.1	17.4	3.5	147.5
Cacaw	15	250	16.7	8.0	5.3	2.9	0.8	99.8
Viejo San Juan	8	247	30.9	22.8	3.8	3.8	1.4	127.6
Catbird	8	103	12.9	6.1	3.0	2.9	0.7	62.7
Milla 7	12	190	15.8	8.0	3.9	2.4	0.4	0.0
Total/Average	53	1394	27.3	15.0	4.6	5.9	1.4	87.5

Among the valuable tree species, *Metopium brownei* was the most abundant followed by *Calophylum brasiliense* (Santa Maria) and *Swietenia macrophylla*. The latter species was only more abundant than *Pouteria spp., Lucuma & Sideroxylon* and Machich because trees with a DBH<20cm were also measured. On average, more than two *Swietenia macrophylla* per hectare are still present. With the exception of *Dalbergia stenvensonii*, all high price timber species are potentially present within FCFR. Nevertheless, only one of each, *Astronium graveolens, Cordia dodecandra* and *Platymiscium yucatanum* was recorded. *Cedrela mexicana* was recorded last year. *Aspidosperma megalocarpon* (Malerio) was only found on the southern part of the reserve in block 5 (San Juan, Viejo San Juan). On average, only one harvestable tree per hectare was found (table 13).

Table 13: Number of valuable timber trees and share of FT, ST and HNY.

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

In two areas (San Juan & Cacaw) not all designated plots could be measured because of wetland areas. For San Juan, an identical amount of plots was measured further down the access road. Coordinates of all valuable trees were documented. Trees can therefore be displayed in a map (fig. 4).

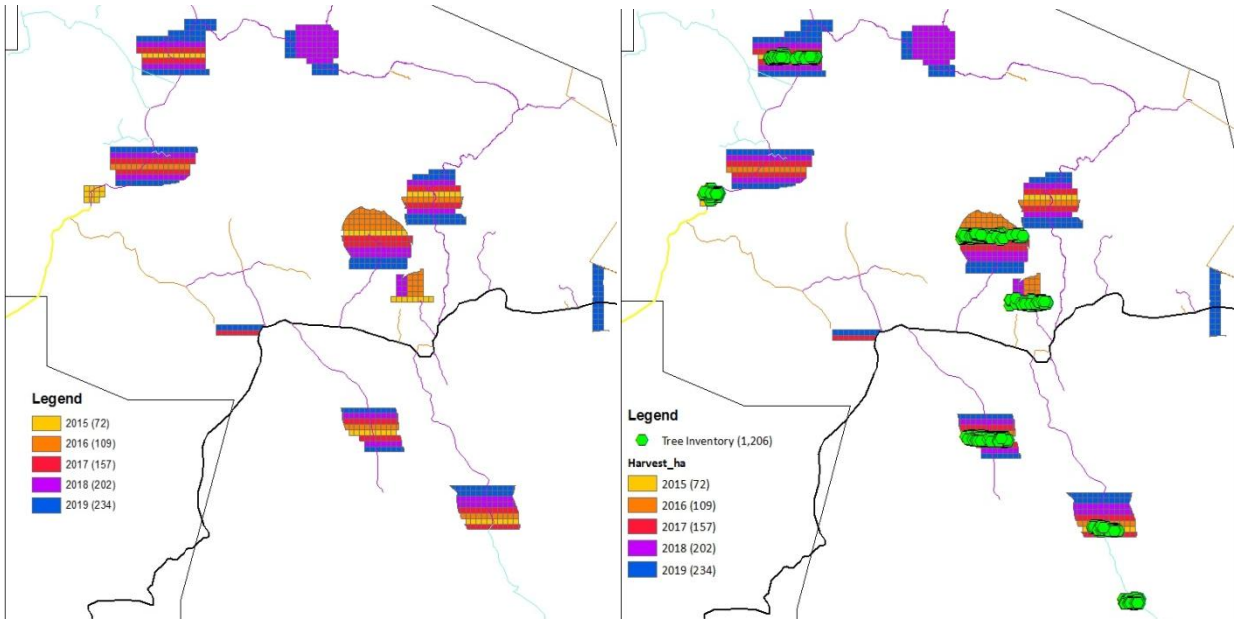

Figure 4: On the left side are the planned areas for stock surveys to be implemented. On the right, the measured trees are visible. Some hectares could not be measured due to wetlands. In one case, the road continued much more than mapped and stock survey was conducted at a new area (south-east).

In future, and when using ArcGIS 10.2© , various spatial analysis can be carried out. For the time being, attributes can be displayed (e.g. DBH, tree species, classification), and this may prove helpful for future forest activities (fig. 5).

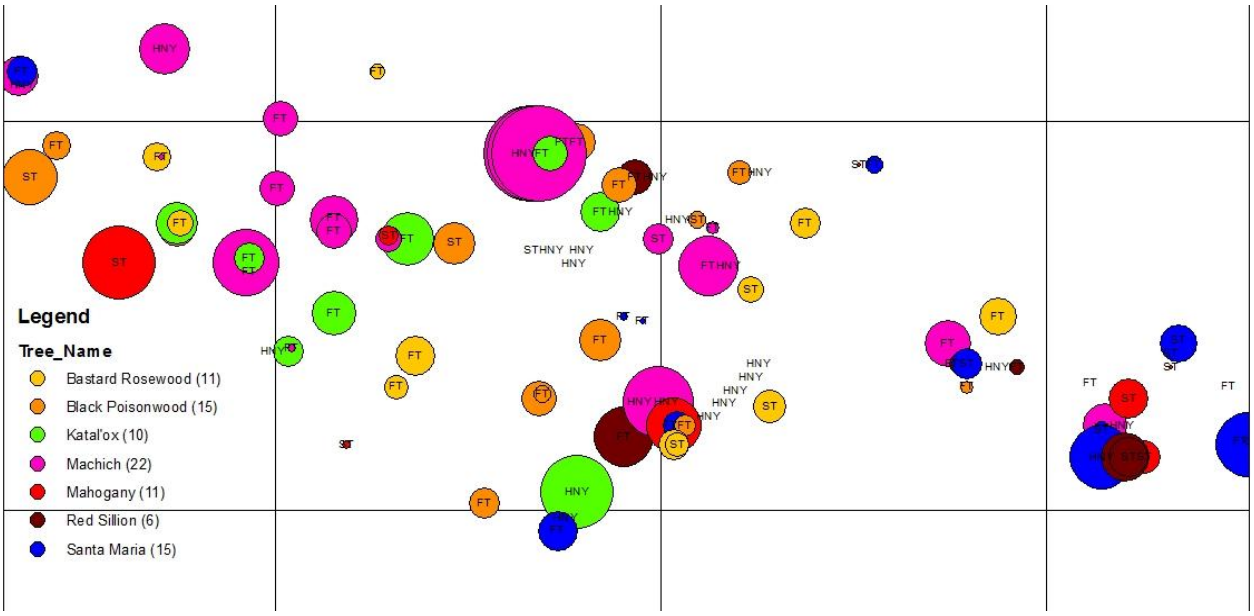

Figure 5: once a stock survey is carried out, trees can be located at a one-hectare level. The size of the circle depends on the DBH of each tree.

4.4 Conclusions

The knowledge about forest conditions significantly improved with the results presented here. For the first time, information was collected in block 5 (San Juan, Viejo San Juan) and block 2 (Cacaw), where within three hectares, every single three with a DBH>20cm was recorded. Unfortunately, last year's findings can be confirmed again: first, few trees with a DBH bigger than 40cm are left (fig. 6). Second, most timber trees have been removed fairly recently. Finally, tree species composition is fairly heterogenous.

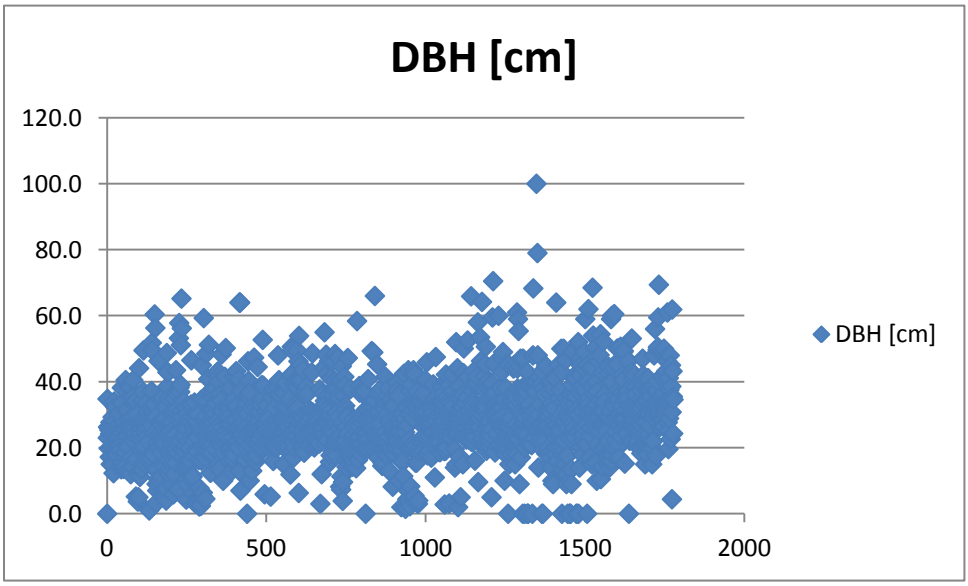

Figure 6: DBH distribution of 1778 trees in the 53 measured hectares.

Despite some trees having been harvested in the FD permanent plot, the forests in that area seem to be in better conditions than in most other parts. Therefore, volume increase and stock may be lower elsewhere.

Although around 35m^3 per ha could in theory be harvested when applying a cutting cycle of 25 years, the volume of harvestable trees today is lower than 1m^3. Very few valuable timber species with a high diameter remain in the area. Extrapolating the income per hectare to the annual harvestable area of around 185ha, an annual income of 16'000 US$ is obtained. This number is not only below expectations, it also far exceeds operational costs to harvest said area.

Since only a small amount (<1m^3) of the potentially harvestable volume (35m^3) can be extracted at the moment, there are two major challenges to address. First, harvestable products need to be diversified. Doing so, more species could be used as merchantable timber wood. Second, the share of timber species and their DBH have to increase significantly. Additionally, access to the international market is highly important. This could increase the income around three to nine times for certain timber species (e.g. *Metopium brownei*).

Stock survey need to be further improved with regard to the quality of data gathered. Knowledge about tree species and tree names need to be improved and standardized. For example, the two different species both known as Machich (*Andira Inermis* & *Lonchocarpus castilloi*) cannot be distinguished by any of the foresters. Nevertheless, this could be important dealing with international timber trading, since *Lonchocarpus castilloi* has a higher value in foreign markets than *Andira Inermis*. Moreover, there is often confusion with species such as Katal'ox and Bastard Rosewood. Foresters distinguish two different species in the field while FD documents the two as one tree with the scientific name of *Swartzia cubensis*, which clearly refers to Katal'ox. Nevertheless, it was not possible to find a scientific name for Bastard Rosewood, and *Swartzia spp. / S. leiocalycina* seem to be the most plausible. A reference herbarium/field guide/field app would be most useful to increase species knowledge.

Overall, few trees reached the defined minimum DBH to make them harvestable. Most of the larger trees appeared slightly damaged (e.g. holes, broken crown, broken braches). Considering that only trees of bad quality were left during previous logging operations, it may be necessary to allow for harvesting to occur within smaller DBH-classes, if properly documented and well founded. If relevant, appropriate agreements should be made with the Forest Department.

Although rangers and other staff possess good knowledge of the area, unfortunately little information is properly documented. Form filing should be improved and data must be properly saved electronically, while further training on GPS (Trimble Juno) is needed. One person more dedicated to data management would be an asset.

Should a statistically reliable spatial overview of the whole area be wished for, a permanent sampling plot grid is much recommended (fig. 7), applying for example the Swiss National Forest Inventory technique. With this method, plots have to be re-measured every 5-10 years to monitor the sustainability of forest management activities. This is an important step to achieve both certification (e.g. FSC) and participation in the REDD+ program.

Permanent Sampling Plots (PSP)

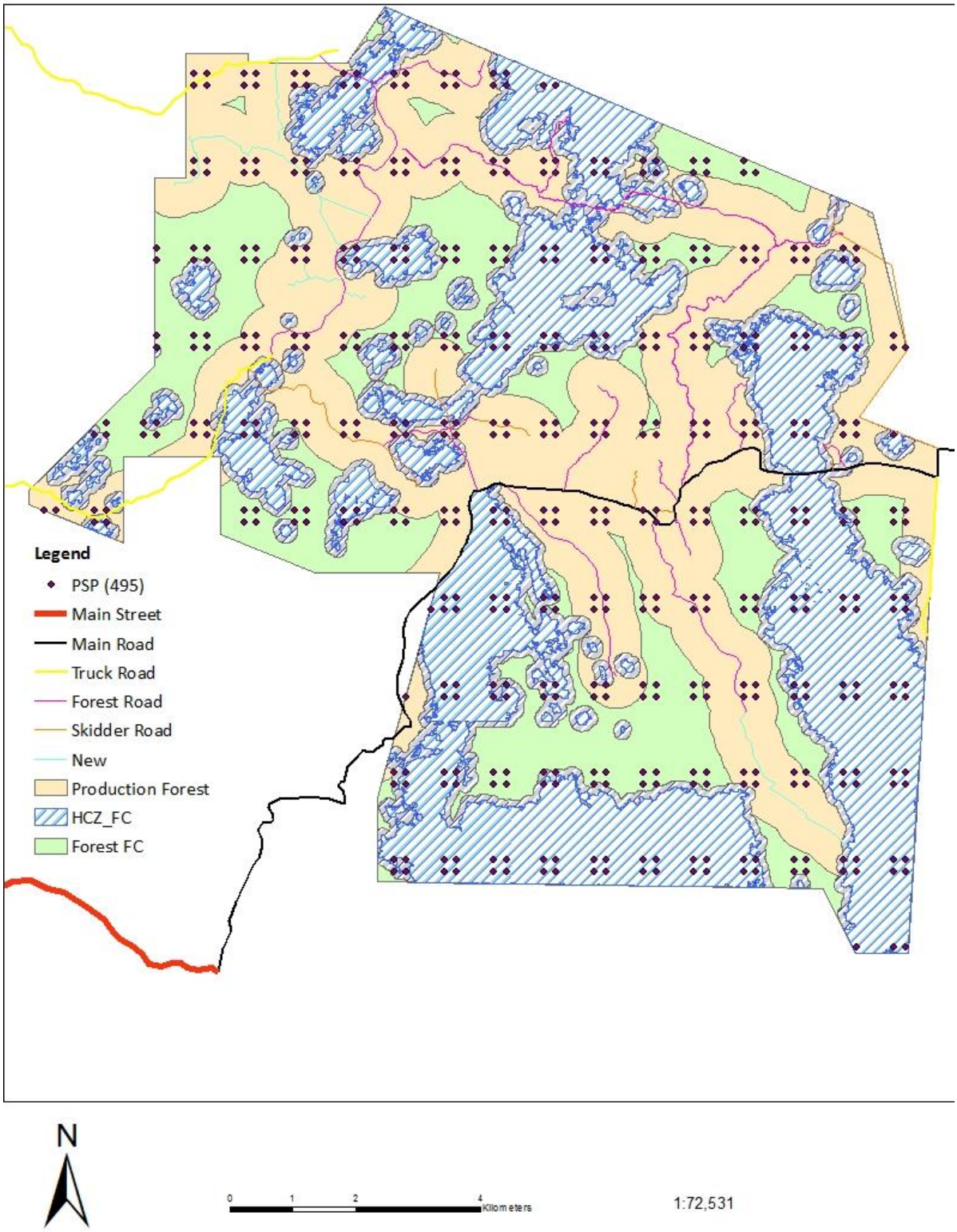

Figure 7: PSP grid covering FCFR.

5 Mahogany plantings

5.1 Introduction

Due to the high level of degradation in FCFR, enrichment with high valuable timber can only be recommended. In view of this, in 2014 a total of 1036 Mahoganies was planted at 19 planting sites along Dos Hermanos (Block 3). Planting sites are very well documented and every second tree was measured and leaves were counted. It is crucial to document the growth of the young trees carefully, as only so can conclusions be drawn about further improvement of plantings.

5.2 Methods

The initial batch of trees planted in June 2014 was measured again in June 2015, i.e. one year after planting. At this stage, only tree height can be measured (fig. 8). Additionally, leaves were counted and tree quality was documented. A special emphasis was given to the detection of potential shoot borer attacks.

Figure 8: Measuring planted Mahogany

5.3 Results

From the 1036 planted trees, 531 are still alive (table 14). This represents a mortality rate of 41.5%. At six planting sites the mortality rate was below 30%. Only three planting sites had rates above 75%. Fourteen out of the nineteen planting sites showed a mortality rate equal or below 50%.

Average increase was 34cm in one year. The highest increase was 124cm. Only six trees have grown more than one meter.

Natural reproduced (NRP) Mahoganies were measured at the following for planting sites: 14, 15, 19.1&2 and 19.3, respectively. Mortality rate of NRP was with 2.4% significantly lower than from planted trees. Surprisingly, with only 14.8cm the growth was also significantly lower.

Shoot Borer damage could only be observed at two trees. Nevertheless, many trees showed a dried main stem replaced by a side branch. Origin of damage could not be identified with precision. Leaves bitten off by leaf cutter ants was the damage most commonly observed.

The high mortality in larger, well sunlit gaps was evident, as planted trees were mostly covered in competing vegetation. On the other hand, trees survived very well on sites where some larger trees were left. These empirical observations of course need to be scientifically documented, and lack of knowledge about influencing factors (e.g. light, nutrition, water) needs to be remedied.

Table 14: Overview of the planting sites with corresponding mortality and growth rates. NRP stands for natural reproduction.

Site NR.	Typ	Nr. of trees 14	Nr. of trees 15	Mortality	Nr. of NRP 14	Nr. of NRP 15	Mortality NRP	n	average increase [cm]	max. Increase [cm]	min. Increase [cm]
2	Road Gap	28	23	17.9%	0			23	51	97	12
3	Road Gap	38	24	36.8%	0			12	40.7	88	8
4	Road Gap	16	11	31.3%	0			4	17.8	32	8
5	Road Gap	50	45	10.0%	0			25	59.7	108	15
6	Bacadillos	100	73	27.0%	0			36	37.4	91	8
7	Road Gap	8	5	37.5%	0			5	40	74	30
8	Bacadillos	77	30	61.0%	1	-		17	46.6	70	27
9	Bacadillos	76	18	76.3%	0			12	14	40	2.5
10	Bacadillos	169	59	65.1%	0			33	22	79.5	2.5
11	Harvest Gap	36	32	11.1%	0			16	32.4	57	1
12	Harvest Gap	50	44	12.0%	0			35	58.8	114.5	11
13	Bacadillos	50	40	20.0%	0			19	48.7	69	28
14	Bacadillos	41	34	17.1%	1	1	0.0%	18	43.2	124	11.5
15	Harvest Gap	12	6	50.0%	63	57	9.5%	63	12.4	34	1
16	Bacadillos	66	35	47.0%	1	-		22	25.7	90	6
17	Forestroad	22	12	45.5%	0			6	17.6	29.5	4.5
18	Forestroad	26	13	50.0%	0			13	21.3	54.5	5
19.1&19.2	Bacadillos	141	24	83.0%	6	6	0.0%	19	25.7	73	2
19.3	Harvest Gap	30	3	90.0%	6	6	0.0%	7	23.7	40	2
Total/Average		1036	531	41.5%			2.4%	385	34	124	1

5.4 Conclusions

In 2014, an unusual bout of very dry weather probably harmed many young trees, and may have caused the loss in main stems subsequently replaced by side shoots. As the mortality was highest in the well exposed areas, drought may have been a main factor more than any other. Also, in some areas, Mahoganies were clearly planted in low depressions, which may have caused them to drown. Finally, some trees may have been planted in soils already too compacted by logging activities (timber yards).

Planting site 15 is of major interest, as it contains four mature *Swietenia macrophylla* with a DBH around 25cm. Under their crown, 63 naturally produced seedlings have been found. This site demonstrates how pre-commercial thinning could enhance natural reproduction of high valuable timber. Simultaneously, future trees have more light available which improves their growth increment. Hence, in other areas where several *Swietenia macrophylla* are found close together, a silvicultural treatment could create similar conditions.

6 Management activities

6.1 Introduction

In the past and as expected, most valuable timber wood species have been extracted from the area. These past logging sessions have had three consequences. First, species composition has shifted from timber wood to non-timber wood. Second, DBH generally decreased, and, with only a few exceptions, only species with low economic – but usually important ecological - value show high DBH. Finally, number of trees with high (timber) quality has clearly decreased. It is obvious that Freshwater Creek FR has been rather badly degraded, and only little economic potential is left.

Bringing back of the original species composition is clearly a priority, as is the increase in the proportion of timber species with high economic interest. Trees competing with remaining valuable and/or still developing timber species must be removed. Also, pre-existing clearings must be opened into proper gaps and planted, in order to enrich forests with valuable timber species. Initially, focus should be given to *Swietenia macrophylla.* In future, planting of *Astronium graveolens, Cedrela mexicana, Cordia dodecandra* and *Platymiscium yucatanum* should be considered and if possible carried out.

Since the remaining economic value of standing trees is very low, the following four management activities will have priority during the next 25 years:

1. Harvesting of the leafs from *Sabal morrisiana* (Botan Wano Palms);
2. Stock survey, mapping and documentation of trees;
3. (Pre-)commercial thinning;
4. Clearing of gaps and planting of *Swietenia macrophylla* (Mahogany).

These activities will be described in more details within the next chapters.

6.2 Wano Harvesting

Non-timber forest products (NTFPs) are derived from various plant or tree parts. Harvest sustainability is often dependent on which part of plants or trees is harvested. A typical example is the cyclical harvest of Bayleaf or Wano Palm (*Sabal morrisiana*) in the Rio Bravo Conservation and Management Area in Belize. The leaves of this palm species are harvested for both subsistence and market use, for the construction of thatched roofs for work shelters, homes and resort cabañas. The harvest of Bayleaf trunks (then known as Botan) and palm heart kills the plant, while the harvest of leaves does not. Leaves are harvested from natural forest stands. Leaf harvesting typically occurs between full moon and up until two days before the new moon. Reportedly, leaves harvested outside this period deteriorate significantly and more rapidly than those cut in the correct phase of the moon. Ideally, all but two leaves are harvested from each individual plant. Two young leaves as well as the central shoot are left intact in order to ensure future growth (O'Hara, 1994). (Report of the International Expert Consultation on Non-Wood Forest Product, FAO 1995).

The Wano leaf market seems to be rather informal, and supply is organized through personal contacts between the owners of resorts on the coast and the reef, and those known to harvest in still existing forests. Therefore, it is difficult to get proper information about market prices. It would seem reasonable to explore potential markets first and contact future customers before starting any harvest.

6.3 Pre-commercial thinning

In FCFR, timber trees with larger DBH and of any value have been harvested. It is also obvious that pre-commercial thinning is a technique that has never been applied to these forests. As a consequence, average DBH has been decreasing steadily and the balance between timber wood and non-timber wood

has been upset. Therefore, species composition does not reflect anymore what it must have been a few decades ago. If only the largest trees keep being harvested – even while respecting legal DBH – it will be very difficult to increase the share of valuable timber species due to the lack of remaining seed trees. Pre-commercial thinning is thus strongly required to ensure both a maximum DBH growth of target species and to increase the number of high value timber-wood.

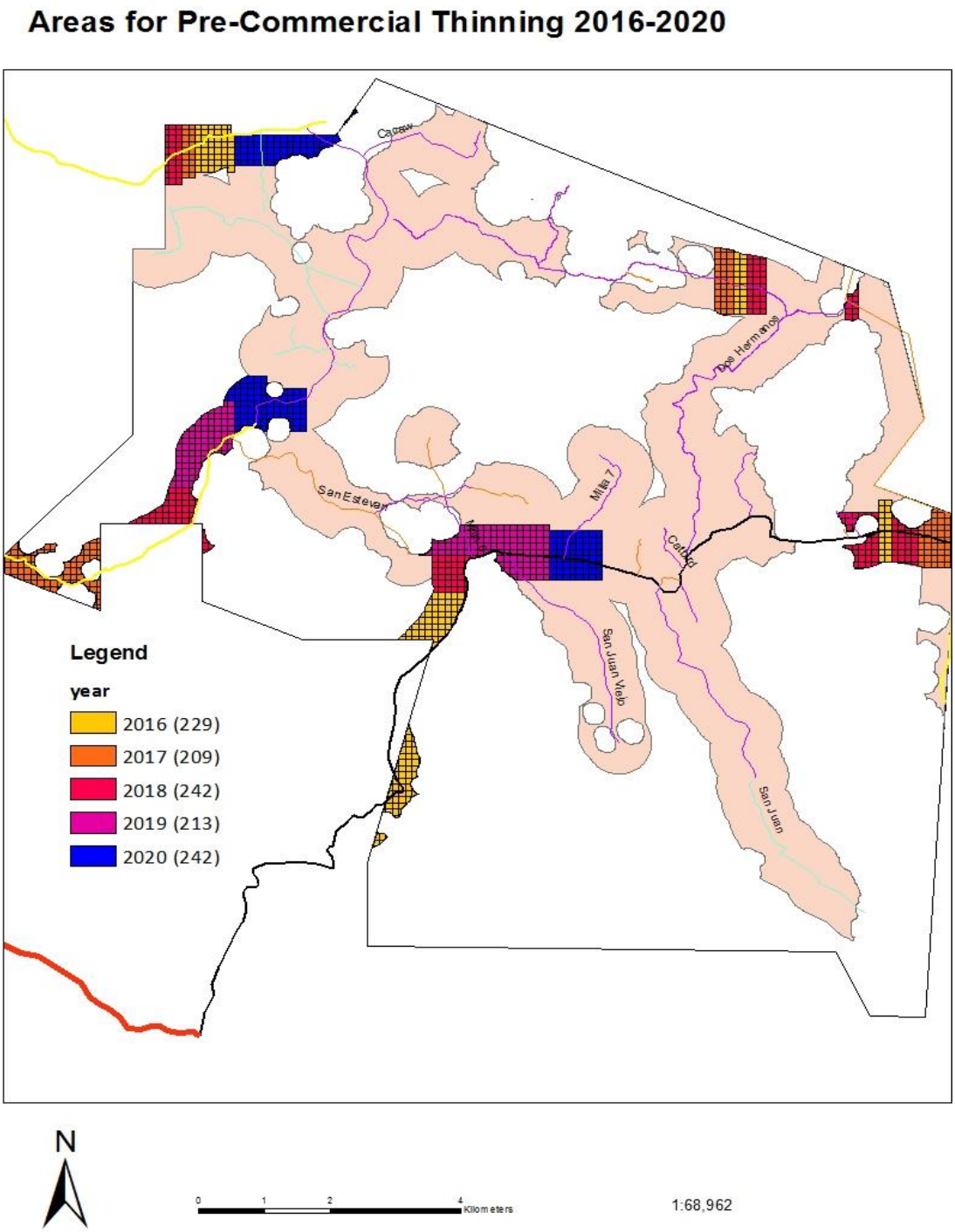

Figure 9: Areas defined for both stock survey and pre-commercial thinning, for the next five years.

When carrying out pre-commercial thinning, a stock survey is first needed to define target trees and mark competition trees. All attributes (species, DBH, DCH, height, quality, classification) of future and seed trees are recorded by GPS (Trimble Juno). Competition trees have to be griddled or cut down, in order to free all future and seed trees free from competing trees and/or crown disturbance. Leaning could potentially arm target trees when falling should also be removed. Figure 9 shows the areas where pre-commercial thinning will be applied within the next five years.

The high price timber-species (table 4), for the time being, must be classified as seed trees. Only specimen of *Metopium brownei* can be classified as future trees, due to the species abundance. Timber species of medium economical interest (table 6) are classified depending on their quality. If they are straight and have a stem height over 10m, they are classified as good. If they are slightly curvy, inclined, forked or have a stem lower than 10m, they are classified as fair. Both mean that these trees are future trees. Quality is bad if they have holes, broken crown or bark damages. In that case they may be considered as seed trees, but only if low numbers make this necessary.

Due to their ecological importance, all specimens of *Pouteria mammosa*, *Manilkara zapota* and *Manilkara* (*Achras*) *chicle* should be classified as habitat trees. They are considered as too valuable for fauna (nesting sites, food, etc.) to be ever logged.

With regard to the overall picture in forest structure (young forest stand, fallen trees, several marked trees together, high value seed tree present, few trees with DBH>20cm), gaps may be opened with a size not exceeding 40x40m (stem to stem) can be opened and should be mapped. These gaps will then be enriched with Mahogany and other hardwood species.

6.4 Gap plantation

With the exception of *Dalbergia stevensonii,* all highly valuable species (table 4) occur in FCFR. *Cordia dodecandra* is now protected and cannot be harvested. Among the highly priced timber species, *Swietenia macrophylla* and *Metopium brownei* are the most abundant. *Astronium graveolens* occurs in medium abundance within the area. *Cedrela mexicana* may be present in some parts of FCFR but not in high abundance.

Presently, *Swietenia macrophylla* is to be found in only very low numbers. However, it is unfortunately the single most important tree species since it fetches the highest prices worldwide (with the possible exception of rosewood, now threatened everywhere. While the evolution in pricing of other species is unforeseeable, *Swietenia macrophylla* will without doubt remain a very valuable hardwood in the long term. As it is a fast growing and naturally occurring species in FCFR, it seems rather logical to focus on it.

Considering that on average only about two Mahoganies can be found per hectare, there seems to be some potential left for natural regeneration. It is actually surprising that after so many years of indiscriminate exploitation there are still Mahoganies left. Nevertheless, since numbers are so low, replanting is unavoidable. Also, it is clear that all remaining trees must be considered as (future) seed trees, to save the long-term genetic viability of local phenotypes. Hopefully, planting may only be necessary during the initial cutting cycle. Remaining seed trees and planted trees will in future hopefully provide enough seeds to ensure natural regeneration, providing thinning and gap creations are continued.

Since very few high value timber species other than Mahogany remain in FCFR, enrichment with these is also highly recommended.

Planting of *Swietenia macrophylla* is challenging not only because it is a light demanding species, which requires large gaps, but also because growing in groups in open areas, it is very susceptible to attacks by the shoot borer (*Hypsipyla spp*). Attempts at natural forest management of *Swietenia macrophylla* have

so far met with limited success, and many plantations are beset by the shoot borer (Lopez et al. 2008). Snook (2005), in the Yucatan Peninsula, recommends gap size of around 5000m^2, opened by either bulldozer or slash and burn in order to successfully plant *Swietenia macrophylla.* However, such large-scale forest operations are neither feasible nor desirable within the scope of the present project.

To reduce impact on forest dynamics, it is our intention to open small gaps, whenever forest structure allows and ideally within the framework of pre-commercial thinning, applying the method developed by Lopez et al. (2008). In FCFR, many small natural and man-made gaps already exist and can be re-opened to be planted. We recommend a maximum gap size of 40X40m (fig. 10). In average about 100 trees / ha should be planted. Multiplied with 185ha, this result in 18'500 plants needed annually.

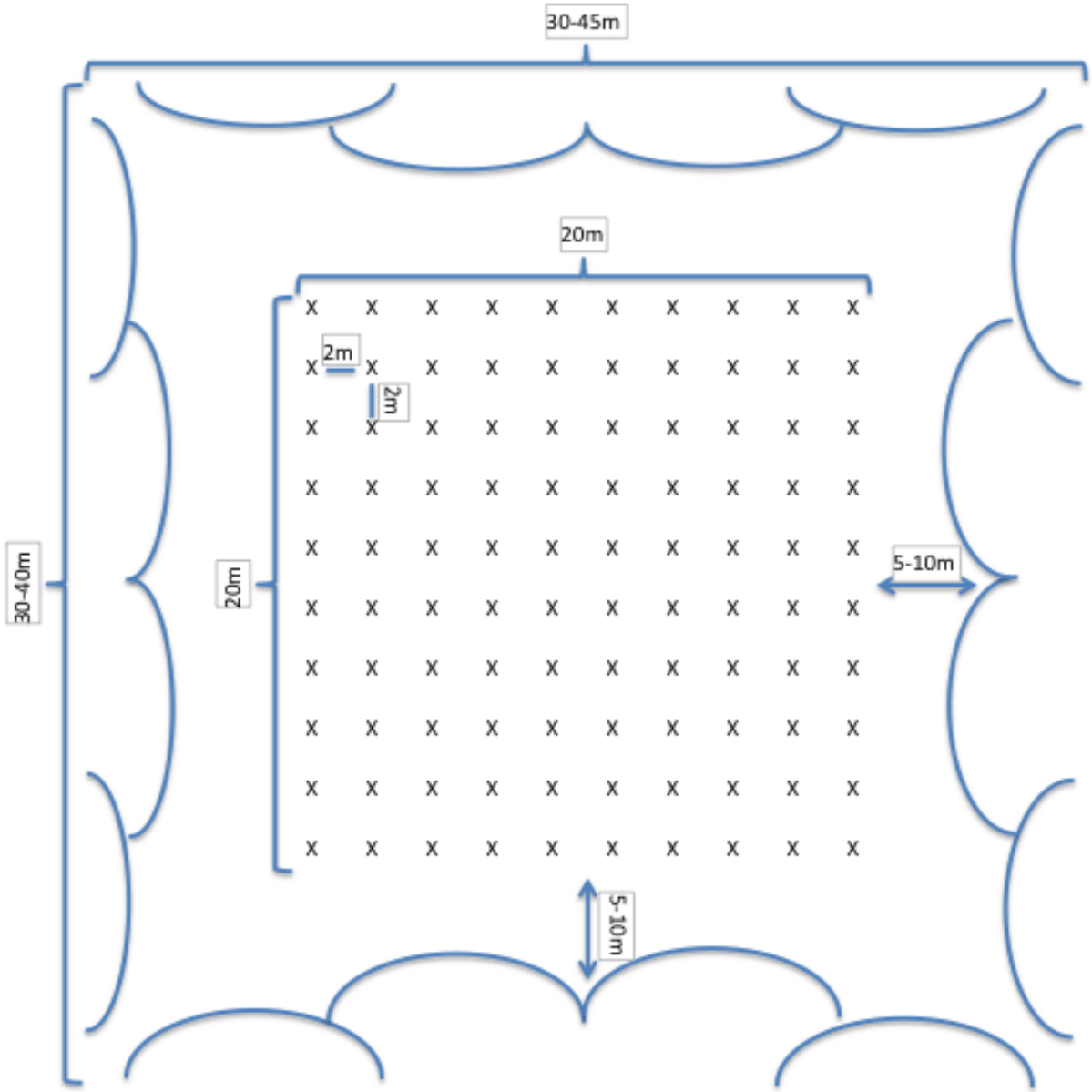

Figure 10: Sketch of gap plantation.

Additionally, during the next five years 20ha/yr have to be enriched with 100 trees/ha (fig. 11) to cover the large existing agricultural areas (100ha). Therefore, a total of 2'000 trees annually for agricultural areas are needed. Hence, around 20'500 trees annually are needed.

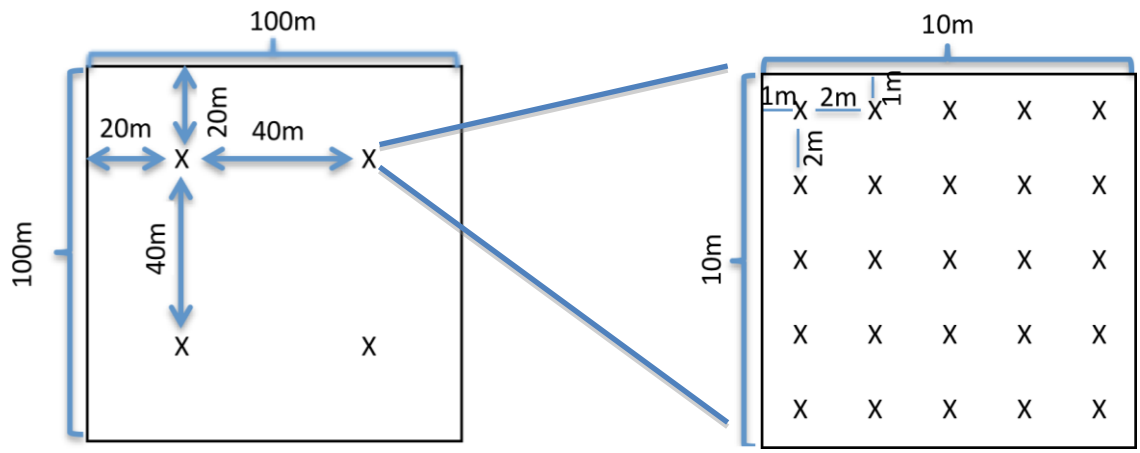

Figure 11: Sketch of plantation in an agricultural area.

To increase genetic variability a high number of seed trees should be selected. Whenever possible, seed trees from the same area (block) – where the seedlings will be planted - are used. Generally, high quality trees are selected for seed collecting. Curved and forked trees should not be used.

On average, 30 out of the 100 planted *Swietenia macrophylla* should survive to maturity. During the second cutting cycle, 15-20 future trees will have to be selected for further growth and given space to grow. Hence, 10-15 young *Swietenia macrophylla* with a DBH of approx. 20cm could be harvested per hectare. In the third cutting cycle, another 5-10 future trees have to be selected. Again 5-10 *Swietenia macrophylla* with DBH around 40cm can be harvested per hectare. Finally, in the fourth cutting cycle 2-5 *Swietenia macrophylla* with a DBH>60 can be harvested, leaving back 3-5 seed trees.

6.5 Reduced impact logging

Conventional forestry in tropical areas has often led to forest degradation and ultimately slash and burn agriculture, depleting some forests to the point of no return. Such conventional timber extraction has taken place in FCFR and surrounding areas, but were never based on any timber-harvesting plan (climber cutting, skidtrail network layout, directional felling, winching etc.), and were generally carried out in a most uncontrolled way.

Reduced impact logging (RIL) is a set of management practices that offers a more sustainable solution to timber harvesting, while continuing to meet rising global demand for tropical woods (TFF 2015).

RIL comprehensively includes the entire spectrum of forest harvesting operations from pre-harvest inventory and planning, selection of merchantable trees and design of infrastructure, to felling, extraction and hauling of logs, and finally post -harvest operations and assessments (TFF 2015). CIFOR (2006) describes the elements of RIL as: proper harvesting planning, forest inventory, preparing contour map, skid trail planning, climber cutting, directional felling and post harvesting activity. The „RIL-Guideline for Indonesia" (2001) describes all steps in detail with many graphs and process-diagrams. This document should be used for training purposes.

An important initial step has already been taken in 2014 with the mapping and definition of high value conservation areas, roads and production forest areas. Within the first cutting cycle, a detailed stock

survey including location of trees with a DBH>20cm is needed, in order to plan proper skid trail networks and directional felling (FAO 26.2.2015). The methodology of the inventory and the pre-harvesting planning is described in detail in CIFOR (2001).

Additionally, investment in equipment has to be done. We suggest the following machines:

- Forest skidder including front lift, two winches (e.g. hudson, farmi) and telescopic crane (lift moment brutto 104 kNm)
- Forest tractor with front gear
- 1 log and 1 bridge trailer (e.g. Kesla)
- Bagger for construction and road maintenance

To reduce soil disturbance and to increase efficiency of forest operations on a mid to long-term (5-10 years) we recommend to improve main roads while upgrading some forest trails to roads.

To ensure high quality of forest management operations employees have to be further trained. Yearly trainings are required. Collaboration with a strong institution (e.g. CIFOR, FAO, CATHIE) would be an interesting possibility.

An example of a sustainable tropical timber wood trade company is Precious Woods in Switzerland. They have many years of experience and built up capacity in Brazil and Gabon. At the moment they control the whole value chain including harvesting, saw mills, veneer, and transport, respectively. They are very concerned about social issues and offer a broad range of trainees also including health and safety. They could serve as a model for future development of the project and, in due course, and when a first harvest cycle starts, a partnership could be sought.

7 Conclusions

In the past and as initially expected, most valuable timber wood species have been extracted from Freshwater Creek Forest Reserve. These past extractions have had three rather dire consequences:

- species composition has shifted from timber wood to non-timber wood
- Average DBH has decreased, and only species with low economic – but usually important ecological – value still show high DBH
- The sheer number of trees with high (timber) quality has clearly decreased.

It is obvious that FCFR has been largely degraded, and only little economic potential is left. Fortunately, the ecological value of the reserve seems to remain fairly intact, with fauna still abundant, as shown by the presence of large predators and now vulnerable species such as white-lipped peccary.

There are about twenty different tree species of economical interest. Knowledge about local and international markets, timber prices and wood products still needs to be improved. 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.

Uncertainties about the volume increase and the stock remains large. It is recommended to gather more data and better volume equations to improve the estimates presented in this document. To achieve a statistically reliable spatial overview of the whole area, a grid of permanent sampling plots is desirable. Long-term research on diameter increase of each tree species with economic interest and under varying growth conditions (light, soil, nutrients, moisture etc.) is highly recommended.

Mahogany (*Swietenia macrophylla)* is a precious, fast growing and naturally occurring species in FCFR. Since few Mahoganies remain, enrichment is necessary. First attempts at planting show satisfactory results. In future, it is recommendable to plant trees in gaps within the forest and not at disturbed or compacted sites like timber yards. It is crucial to further observe and document growth of young trees carefully, in order to be able to reach valid conclusions about the success of gap plantations. With regard to the latter, Planting Site Nr. 15 gives a fair idea about how pre-commercial thinning can create in forest gaps and what these would look like.

As a conclusion, one recognizes that CSFI's Sustainable Forest Management Project at FCFR has the potential of becoming an outstanding example in Belize, not only with regard to conservation, law enforcement and sustainable forestry techniques, but also to social aspects and working conditions. It is therefore important that at each stage, thought is given to properly define decision processes, responsibilities and clear tasks. Annual and monthly plans are highly recommended and are essential when welcoming new employees. Additionally, documentation and controlling processes should be continuously improved. Weekly group meetings should be established to improve communication and help plan and implement short-term and mid-term activities. Combined with further incentives for employees, this will help avoid turnover among staff and help build up in house capacities on the long term.

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