# Freshwater Creek Forest Reserve (FCFR) Sustainable Forest Management Project Forestry Annual Report 2014

Corozal Sustainable Future Initiative (CSFI) – March 2015

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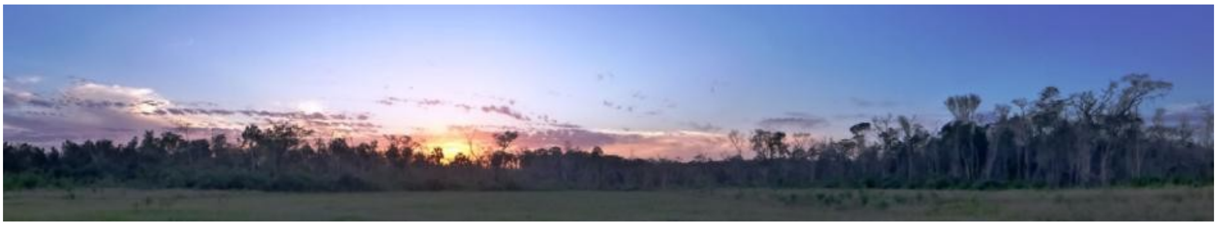
# 1 Introduction



*Sunrise in Freshwater Creek Forest Reserve (FCFR)*

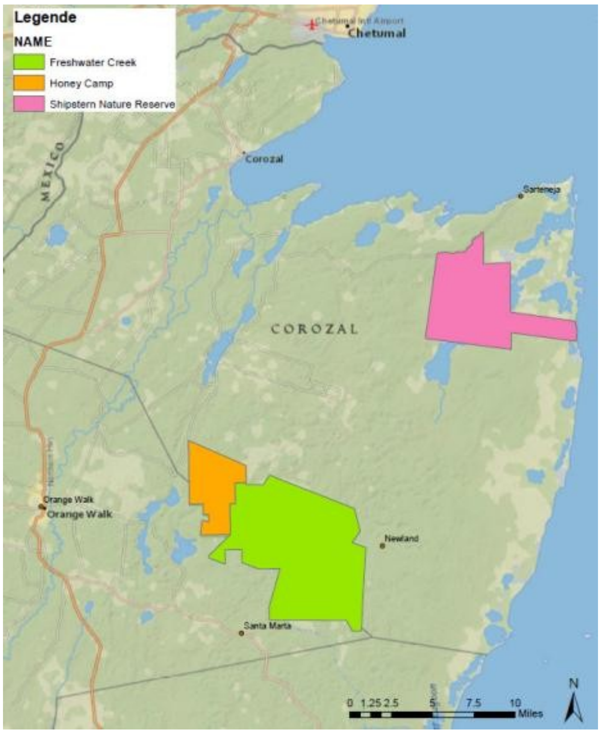
On May 14, 2013, the Corozal Sustainable Future Initiative (hereafter CSFI) signed an agreement with the government of Belize pertaining to a long term concession to manage Freshwater Creek Forest Reserve (hereafter FCFR) for 42 years.

CSFI's initial forestry project started in January 2014. During the first year, its main objective was to gather basic forestry data for FCFR, as well as to gain preliminary silviculture experience within the forest reserve itself. Further aims included the definition of various forest management strategies and the preparing of a work plan of activities within an initial 5-year trial phase. CSFI teams were assisted in this by Pascal Walther, a professional forester from Switzerland, who volunteered for seven months within the framework of the Swiss Civil Service, an alternative to compulsory military service. His partner Esther Aemisegger also volunteered and was instrumental in developing the tree nursery and production facilities at Shipstern N.R., while also researching germination techniques for Mahogany.

The core objectives for the forestry project in 2014 were: general mapping of the reserve; first inventory and analyses of forest stands; design and construction of nursery infrastructure; and production of several thousand Mahogany trees (*Swietenia macrophylla*), as well as several hundred Spanish Cedar (*Cedrela odorata*) trees, both from local phenotypic stock. Last but not least, the project aimed to gather a maximum of experience in the field, i.e. reforestation methods, pre-commercial thinning and analyses pertaining to the potential of natural reproduction of local hardwood trees. Data of all project steps were thoroughly documented.

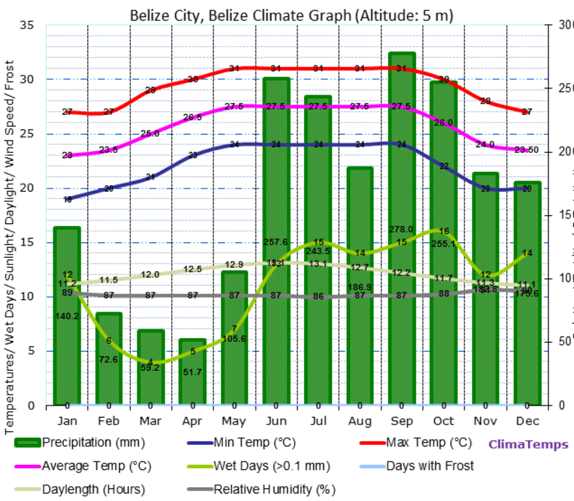
Because this report deals only with forestry activities, further activities carried out in parallel and pertaining to FCFR (negotiations, law enforcement, re-opening of boundaries, construction of border markers and signs, among others), are not included.

# 2 Background




Belize, a small Central American country in the south-east of the Yucatan Peninsula, is situated between Mexico and Guatemala on the Caribbean Sea. It extends over about 23,000 km$^2$ and is still fairly sparsely populated with approximately 350,000 inhabitants. Belize's forest cover is still above 50%, which in relative terms makes it the most forested country in Central America. However, deforestation and land conversion have increased significantly in recent years, and this percentage is bound to drop in the coming years.

Belize's tropical climate is characterized by an intense rainy season from June to December and a dry season from January to May. The annual average temperature is 25.9 degrees Celsius and annual precipitation is ~1,865 mm. The north-east of Belize is the driest region of the country, and here rainfall is markedly below the country's average. Exact climatic data for the north-eastern region are not yet available and are in the process of being recorded by CSFI.




*Source:* http://www.belize.climatemps.com/

Freshwater Creek Forest Reserve, as its name indicates, allows for sustainable forestry activities, with clear management processes within designated non-HCV (High Conservation Value) areas. In the past, both legal and illegal logging activities in FCFR have eventually depleted the forest of valuable and harvestable timber, while more recently illegal encroachment has further degraded some parts of the reserve. Unfortunately, these past practices have solely focused on timber harvesting, while silvicultural methods to enhance the quality, stability and biodiversity of the forest were never undertaken.

The situation is now under control, thanks to much effort by CSFI's teams, often assisted by the Forest Department and the Police. Extreme vigilance is nevertheless needed to prevent any further illegal activities in future. The fact that FCFR is located between the community of Santa Marta and the new Rheinländer Mennonite community, both connected by a busy forest road dividing the reserve from east to west in two equal halves, will not make this task easier.


*Above: a truck carrying logs, driving through FCFR, is being checked by CSFI's team*

The Freshwater Creek Forest Reserve (FCFR) is one of three protected areas managed by CSFI in northeastern Belize. The other two, the *Shipstern Conservation and Management Area* and the *Honey Camp National Park* are IUCN category II protected areas, i.e. national parks, and both managed as such. This includes surveillance to prevent illegal logging, poaching and encroachment as well as promoting sustainable tourism and environmental education.

# 3 General Mapping

*Mapping team returning from long days of field work*

In 2014, one of the primary objectives for CSFI was to conduct an intensive exploration in order to create a general map of FCFR. Based on high resolution satellite imagery and geographic information systems (GIS), combined with field visits to confirm initial assumptions, it was possible to develop a first detailed digital map of FCFR. This map includes all forests (classified along forest types when feasible), water bodies, wetlands, savannas and (illegal or recovering) agricultural areas. In due course, it will be refined in order to include all vegetation types in the area. The map will form the very basis for sound management decisions in regard to activities within FCFR.

## 3.1 Baseline

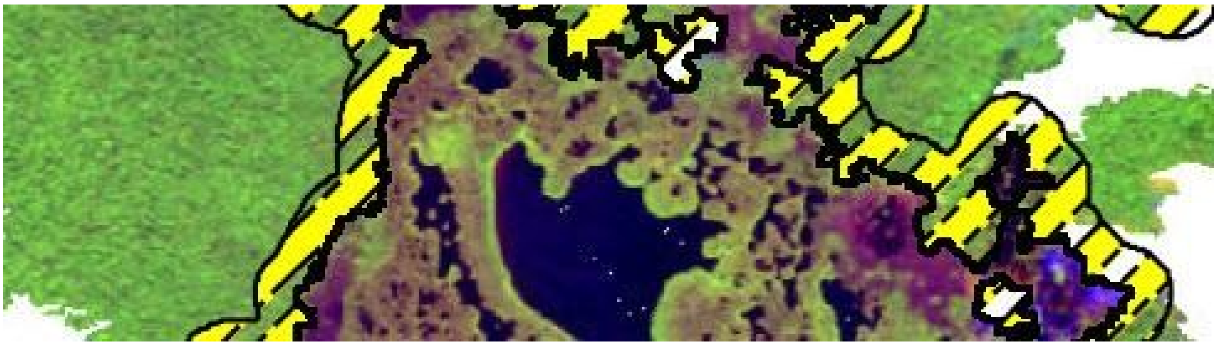
As local landscape and ecosystem maps are rare or non-existent, mapping of the area had to be started virtually from scratch.

## 3.2 Objectives in 2014

- General mapping of FCFR based on satellite imagery and GPS positions taken in the field
- Develop first draft of land cover, vegetation and road map
- Generate forest management maps (definition of high conservation value areas, production forest, forestry roads, etc.)
- Land cover surface calculation
- Photographic documentation of existing ecosystems, vegetation, and forest types, as well as individual landmarks

## 3.3 Implementation

### *3.3.1 Satellite imagery interpretation*



*Satelitte imagery interpretation: Forest / Buffer / Wetlands / Waterbodies*

In order to manage and archive a vast array of GIS and other data, CSFI has set up a GIS Database. With the help of various ArcMap classification tools, CSFI has created initial land cover and vegetation maps based on 2011 Rapid Eye satellite images, bearing a resolution of 5 meters per pixel. The data are of high quality, however they are partly impaired by clouds and cloud shadows preventing the proper classification of land cover. These gaps in data can nevertheless, in most cases, be alleviated by using data generated through Bing, Google Maps, Landsat etc.

Comparing the map created through this process with Rapid Eye imagery from 2011, it is clear that substantial deforestation occurred around FCFR and to some degree even in the park, between 2011-2014. CSFI teams now continuously monitor all small clearings inside FCFR, from detection to positioning, and from surveillance to recovery.

### 3.3.2 Field mapping

Digital data are being checked and loaded into the GIS Database on a continuous basis. During field trips, vegetation types are recorded, mapped and photographed. This process has led to the discovery of an impressive amount of hidden natural features. Field trips have unearthed evidence of higher presence of wildlife than expected, including many rare or endangered species. A more in-depth survey of the fauna of FCFR will take place in 2015.

A substantial amount of data on forest roads, illegal agriculture, natural and anthropogenic gaps in the forest are recorded by GPS mapping during missions carried out on foot and motorbike. Although mapping is the priority of these field missions, they do provide a strong presence within Freshwater Creek FR, and have already helped to detect several cases of illegal activities. In total, more than 100 hectares of illegal agricultural plots were discovered and stopped in 2014.

## 3.4 Land cover of FCFR


*Freshwater Creek, a mosaic of forests and wetlands*

FCFR is a mosaic of habitats. Dominant elements are forests of various types, distinctive in forest structure and species, as well as wetlands in various forms.

The landscape of FCFR is flat to slightly hilly, with a maximum difference in height of about 15 meters. Geologically, the parent rock consists of limestone, which often protrudes at the surface. In places, some hills and lower parts are intertwined and heterogenic, while other larger areas can be quite homogenous in altitude, either as plateaus or lowlands. The latter are usually flooded in the rainy season. Logically, the topography is one of the main factors dictating vegetation types.

## Hydrology

*“Blue Hole” Lagoon*

The hydrological features of FCFR were not analyzed systematically in 2014, but some observations have been made. Within the Reserve, large freshwater and brackish water lagoons, small ponds, streams and seasonally flooded areas can be found. Some of these wetlands dry out in the dry season. Vegetation within these wetland systems varies, ranging from marsh forest to grass savannahs or dwarf mangroves. Particularly impressive is the "Blue Hole" of FCFR. It stands out from other lagoons by its impressive light blue coloration, which can be clearly recognized in satellite imagery. Unfortunately, only part of this lagoon lies with the reserve. Subterranean hydrological systems are unknown at present.

## Forests

*Members of the CSFI team in front of a large Santo Domingo tree*

Forests in Freshwater Creek FR are very heterogeneous in nature, due to natural variation (for instance soil composition and topography), environmental factors like hurricanes, and anthropogenic impacts. Species composition and structure may vary even on a rather small scale, and mosaics of forest types are common. Despite this, forests can be divided into main categories covering large and contiguous forest tracts, their distribution being linked to topography and resulting soil types. On higher grounds, the canopy of broadleaf forest (or Yucatan high seasonal forest, to follow the Mexican terminology) can reach up to 30 meters. In lower parts and/or on poorer soils, the canopy of medium-sized seasonal forests reaches only 15-20 meters. Species composition and stock also differ between these formations.

In addition, Freshwater Creek is home to many types of marsh forests, riverine forests and even mangrove communities. Their ecological value is considered to be high, since many have been reduced drastically over the past decades, not only in Belize but also in neighboring countries. Today, in view of the high deforestation rate over the past 20 years in northeastern Belize, the conservation and long-term sustainable management of Freshwater Creek have become critical, as this reserve may soon contain the last remaining stands of seasonal lowland forests in Belize.

## Grass Savannas

Within Freshwater Creek, significant stands of grass savannas can be found. These habitats tend to be under water all year. As a result of natural succession, topography and changes in the hydrological system, this vegetation type is interlocked with marsh forests. This sensitive savanna ecosystem provides valuable habitat for many species.

## Flora and Fauna

*A remarkable number of orchids and other epiphytes adorn the forest communities of FCFR.*

The many field missions undertaken in 2014 identified an abundance of wildlife still present in FCFR. Species recorded, either through sightings, droppings, footprints or other evidence of existence, include: Jaguar, Puma, Baird's Tapir, White-lipped Peccary and Collared Peccary, White-tailed Deer, White-nosed Coati, Great Curassow, Toucans, various reptiles, amphibians, and many more. In 2015, CSFI will start a more detailed research into key species, using camera traps, and prepare the outline of a long-term Monitoring Program for selected sensitive species.

### Illegal agriculture

*Illegal deforestation within FCFR, June 2014*

CSFI began implementing conservation measures in FCFR immediately after signing the concession agreement. It came as a shock to discover that within the last five years, over 90 slash-and-burn areas had been opened, covering a total of almost 250 acres. Nearly all areas were dealt with, as the owners were unable to give proof of land title and acknowledged their trespassing. CSFI handled the matter diplomatically, allowing farmers to harvest annual crops before leaving.

### Forest roads and skid trails

Over the past decade, an extensive network of forest roads has been built, either in the framework of a forest concession or illegally. This network is in poor condition, but important for future forest management.

In 2014 the access roads and the various forest roads and skid trails within the Reserve were assessed, categorized and inventoried. On flat ground in limestone areas, the forest floor is clearly very sensitive: Extensive soil damage and degraded roads, due to recent logging activities, are still visible. The poor condition of roads may have adverse effects for CSFI forest management, mostly in terms of safety, efficiency and sustainability – this is a matter which will need to be addressed when extraction starts.

The network of skid trails was clearly uncoordinated, and heavy machinery caused damage by compressing the sensitive forest soil. One of CSFI’s important objectives in future management is to avoid any expansion of damage to the forest floor by making use of existing skid trails and road network layout. New trails and roads should not be created unless absolutely necessary.

**Differences between digital data and field data**

The perimeter of protected areas is given in the official GIS Layer of the National Reserves of Belize. However, when CSFI reopened and marked reserve boundaries, it discovered some discrepancies between map and reality. These are currently being addressed with the proper authorities.

### 3.5 Management Maps

Based on satellite imagery, field mapping data and conservation and forestry requirements, CSFI developed initial management maps for FCFR. These intend at first to be a basis for discussion, and will be refined during the development of the FCFR Management Plan, with the help of both Belizean and international experts.

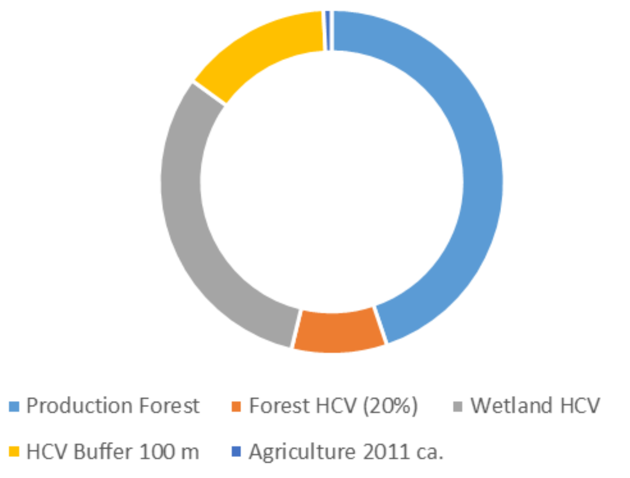
**Zoning**

Mapping in 2014 allowed for the identification of High Conservation Value areas (HCVs). These include all wetlands with open water bodies, swamps, savannas and marsh forests. In all, the HCVs represent approximately 10’000 acres (4’000 hectares), or 30% of the total area of FCFR.

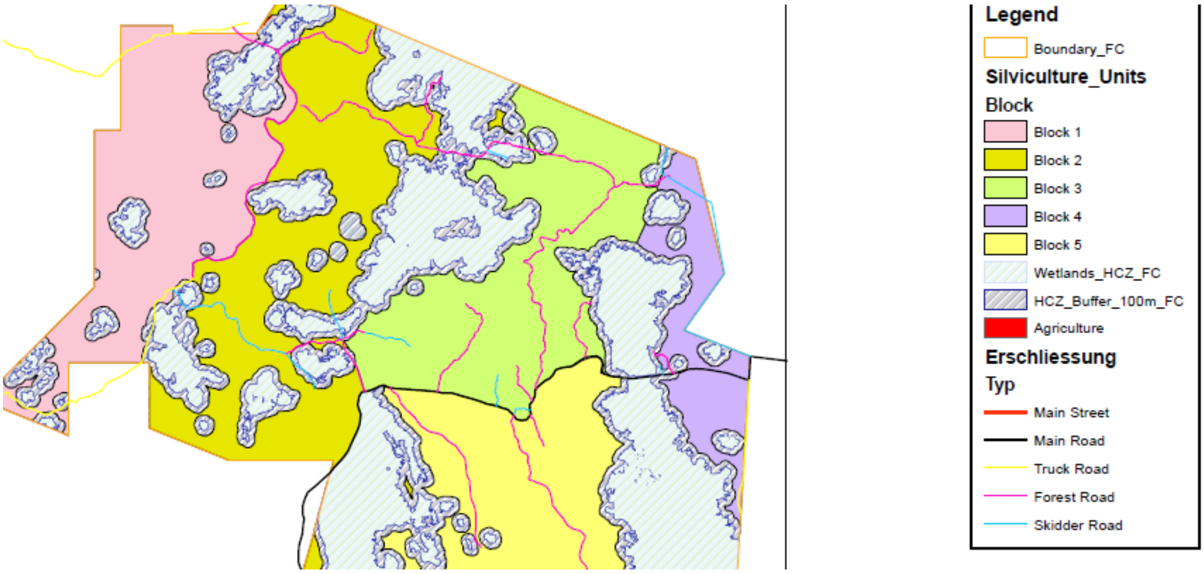
To ensure both functionality and integrity of habitats transitioning between HCV and surrounding forests, maps include a buffer zone of 100 meters to be conserved around each HCV. This buffer adds another 4,500 acres (1850 hectares) of forests to the strict conservation zones, or in other, words, or 14% of the total area of FCFR. It is CSFI’s intention to eventually designate another 20% of the total of FCFR as forest conservation areas / seed bank zones. This designation will be happen gradually as forest zones are being explored and understood.

In total, 56% of the total area of FCFR has been classified as strict conservation zones. Inside these zones, no forestry operations will be allowed other than seed collection.

The remaining 44% of the area (14,250 acres or 5,850 hectares) has been designated as “production forests.” The intention is to manage these through sustainable and low impact forestry operations. The graphic to the right shows the relative surface areas of the different land use designations.

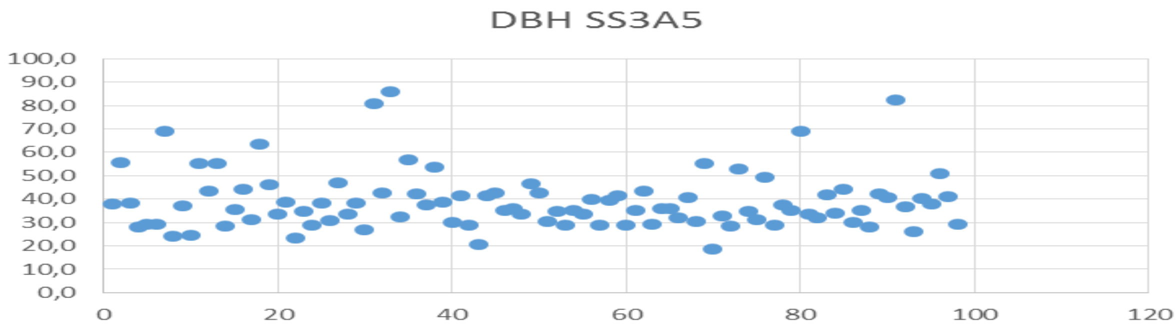


### Forest Management Maps




In order to plan forestry activities, forested areas were divided into five management units, according to natural borders and with road and trail networks taken into practical consideration. As mentioned above, these designations will require further fine-tuning to create an efficient tool for forest management.

# 4 Forest inventory program FCFR 2014




*Diameter class distribution from a one-hectare stock survey in FCFR (excerpt; DBH in cm)*

Forest inventories are essential in providing information on the various forest communities and their structure, stock, growth, species composition, quality, among other aspects. A regular repetition of these inventories in permanent plots allows for a better understanding of natural dynamics and evolution within these forests. They also show any changes in ecosystems, in particular in regard to growth rates. Such information is at the core of sustainable forest management. Forest inventory data universally use the metric system.

### 4.1 Baseline

At the start of the project, forestry-related data in and around FCFR was insufficient to develop a proper forest management plan. The few available data emanated from a one hectare permanent plot created by the Forest Department. Forest structure and potential as well as species composition were only vaguely known, while the presence or absence of large seed-bearing Mahoganies was completely unknown.

When work in the field started in 2014, only a minimal amount of equipment needed for forest inventory work was available, and thus only a limited area could be investigated. The data gathered did provide a verifiable, localized insight into the forest structure and composition, but due to the heterogeneity of forests within FCFR, it may not yet be very representative of the Reserve's forests as a whole. It is hoped that this gap in data will be closed within the coming years.

*Right: Lester Delgado with the finest Mahogany so far discovered FCFR*

### 4.2 Objectives for the 2014 Forest Inventory

The 2014 objectives for the FCFR forest inventory activities were to:

- Conduct a field trial of four different inventory methodologies
- Identify avenues for participation in the national forest inventory program of Belize
- Develop a long-term forest inventory concept for FCFR
- Build up CSFI's internal capacity to carry out forest inventory, including human resources and equipment.

### 4.3 Forestry Inventory Implementation in 2014

To meet these objectives, the following activities were undertaken:

- Installation of a one-hectare Permanent Plot in Block Nr. 1
- Installation of 25 random Permanent Sampling Plots (PSP) in Block Nr.1
- Stock survey in 10 hectares in Blocks Nr. 1 & 3
- Inventory of special trees during field missions
- Forest inventory trainings for CSFI's team
- Initial investment in inventory equipment

## 4.4 Inventory methodologies

*Lunchtime during a hard inventory field week*

Many different forest inventory methodologies are used worldwide, with thousands of possible attributes being recorded depending on forest ecosystem interpretation. CSFI is just beginning to learn about the forest ecosystem and natural dynamics of FCFR, a process which takes generations. In 2014 CSFI limited its forest inventory work to exploring how to collect short and long-term data concerning:

- Species composition, diameter and age classes, tree heights, and the different forest communities
- Growing rates and the natural dynamics of the forest ecosystem
- The effects of anthropogenic or natural impacts on the forest ecosystem

A particular challenge will be collecting this type of data over larger areas of FCFR and not just in small study areas. This is necessary because FCFR is very heterogenic

To maximize our limited resources, the team decided to use four different inventory methodologies and to reduce the number of attributes to be studied. The four different methodologies are described below; the measurement techniques used are based on the national field manual “Rainfor” (NER/Belize).

### *4.4.1 Single tree Inventory*

This involves noting the GPS points of Mahogany and other large or special habitat trees found during field missions. Around 400 trees were mapped this way; diameter at breast height was measured for half of them.

### *4.4.2 One-hectare Permanent Sample Plots*

*Plot Inventory*

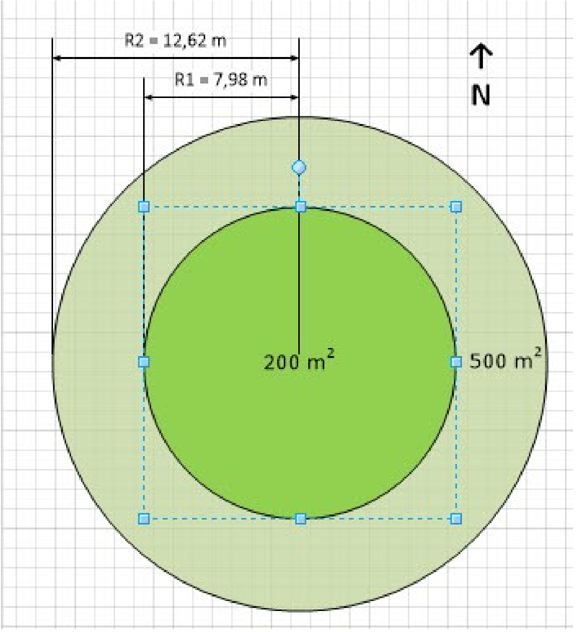
Monitoring one-hectare (100 by 100 Meter) permanent sample plots (PSPs) over time is the best way to collect quality data regarding the long-term evolution of forest ecosystems. The Belizean National Forest Department has created an exemplary permanent plot forest monitoring system in forests all over Belize under the direction of Forest Engineer and Commissioner Dr. Percival Cho. One of the plots of the national forest inventory grid is located inside FCFR. This plot had been accessed once but had not been continuously monitored.

While plans to re-measure this plot in 2014 had to be cancelled because of an emergency involving illegal logging elsewhere in Belize, followed by inclement weather, the aim will be to try again in early 2015, together with Forest Department staff who will then use the opportunity to train the CSFI team in the national forest inventory methodologies. Dr. Percival Cho has also recommended that additional PSPs be set up in different forest communities. In 2014 one new plot was established in Block One, and half of its trees were recorded. The plot will also be finished in early 2015.

### *4.4.3 Random Permanent Sampling Plots (PSP)*

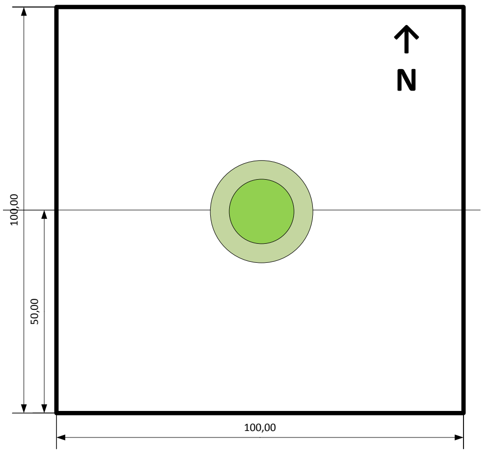
To acquire quality forest data from a larger area in FCFR, CSFI aims at setting up random permanent sampling plots PSP, distributing these fairly evenly over a given area within FCFR. In 2014, the team focused on a section of Block 3, with PSPs located relatively close together. In the future CSFI hopes to expand these PSPs over larger areas. Also, we shall determine whether the PSP forest inventory technique is compatible with carbon monitoring for REDD+ or other carbon projects.

The steps in setting up a PSP are described below.



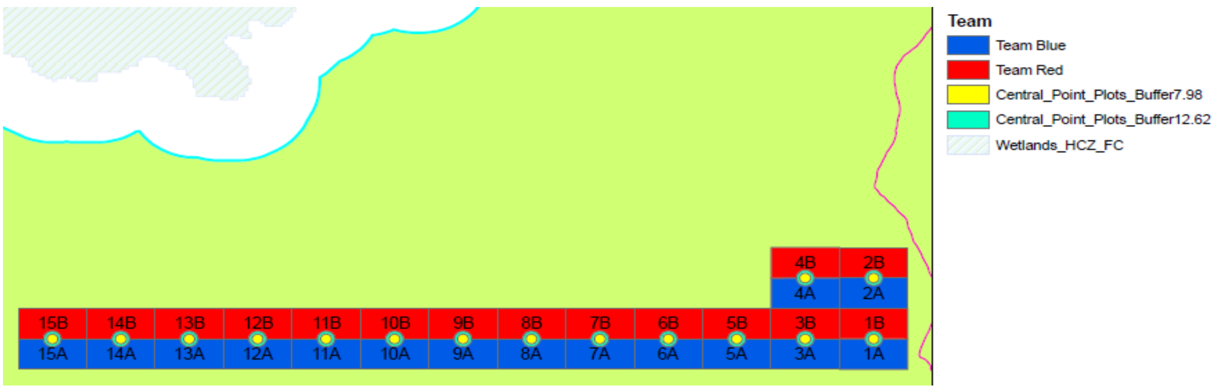

- Open a straight East / West Survey line according to the compass and mark it with color or tape.
- Mark the center of the PSP with durable wood pole and iron stick, and take the GPS position
- Two circles are delineated from the center point; one with a radius of 7.98 m (r1) and area of 200 m2 and one with a radius of 12.62 m (r2) and area of 500 m2.
- Within the smaller circle, every tree which has a diameter larger than 12 cm is recorded
- Within the larger, every tree which has a diameter larger than 30 cm is recorded
- Data collected include species, diameter at breast height (DBH, measured at 1.3m), quality, and quality.
- From 2015 onwards, additional data will be collected (tree height, diameter at a height of 7 m, dead wood, etc.)

### *4.4.4 Stock survey*




To assess the presence of Mahoganies and other outstanding trees, CSFI decided to do stock survey within the hectare surrounding each PSP. Mahogany and other commercial species with a dbh of at least 30 cm were recorded, as were any large “habitat trees” of 60 cm dbh or more. The diagram to the left shows the extent of the stock survey around the PSP.

Stock survey and establishment of PSPs was done in three teams. One team opened the survey lines and did the PSP inventory, while the two other teams did the stock survey around the PSP.



### 4.5 Summary of inventory and forest analyses


*Team instruction inventory work*

With regard to the broadleaf forests of Block Nr 1 & 3 of FCFR, the following can be stated at this stage:

- Analyses of inventory data show that forest structures in FCFR are very heterogenic, for various reasons:
  - Natural variation in forest stands and ecosystems
  - Changes caused by previous logging
  - Changes following storms and hurricanes
  - Trees with attractive shape and volume of at least 50 cm DBH, and thus of economic interest, are rare.
  - Trees of 50 cm dbh and greater, with low or no economic value, are still quite abundant
- All inventory units show a dominant diameter class of 30-50 cm DBH within various tree species of decent shape and good economic value.
- In most one-hectare units, there at least one to four Mahoganies with a DBH between 20-30 cm, as well as other marketable species.
- One to three old Sapodillas (*Manilkara zapota*) bearing sap-collecting scars were found in most one-hectare units.
- There are a large number of trees of special interest, for instance habitat trees
- All one-hectare units possess at least one and sometimes two natural or anthropogenic gaps, harboring young forests stands (2 – 10 meters in height)
- Dead wood (dead trees, or branches resulting from wind damage) is abundant in all inventory units
- Besides the aforementioned illegal agriculture areas, no other large-scale clear cuts were encountered in the previously logged areas
- Key data such as stock / ha are not yet available, as they are being processed. These will be presented in the next report.

### 4.6 Conclusion


*CSFI forest inventory team 2014*

Based on the initial forest inventory, the following conclusions can be made:

- Trees with good economic value of at least 50 cm have mostly been extracted by selective logging
- The last logging concession (and/or the continuous illegal logging) focused solely on the extraction of valuable trees, with no regards for sustainability.
- Overall, the forests do not have much potential for logging at the present stage.
- However, a large number of valuable tree species with dbh from 30-50cm will grow into proper harvestable diameter within 10 -20 years
- The quality and stability of these future forest stands can be optimized through proper silvicultural thinning and selection.

The consistency of these conclusions should be tested for all forestry blocks within FCFR

# 5 FCFR Silviculture program 2014

CSFI forestry team

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

In 2014, CSFI decided to focus its initial forestry efforts on young forest stands. To this aim, it chose to work with both natural and anthropogenic gaps found in the forest of FCFR.

## 5.1 Baseline

During previous logging concessions, most trees of high quality and economic interests were removed from FCFR, while less interesting trees were untouched. This has heavily influenced forest composition as well as economic value as a whole. CSFI proposes to invert this tendency, by the rational use of silvicultural treatments, in order to reestablish a proper balance of valuable trees and natural occurring but not economically interesting trees

## 5.2 Silviculture program – 2014 objectives

The objectives of the silviculture program in FCFR in 2014 were to:

- Acquire experience and data in stand establishment through gap plantation
- Open and prepare planting sites
- Identify good Mahogany mother-trees and harvest their seeds
- Evaluate various planting methods and plant approximately 2000 Mahogany trees
- Analyze the potential for natural reproduction of economically valuable trees
- Undertake Pre-commercial thinning in young forest stands
- Document all planting sites
- Train CSFI's forestry team

## 5.3 Implementation of silviculture program in 2014

### 5.3.1 Gap Planting

One of the desired goals of the silviculture program is to start restocking forests in FCFR with Mahogany and other valuable timber tree species, in natural or man-made gaps. This forest management technique is being implemented with success in other countries, whereby gaps with a diameter of 10 - 25 meters are created through selective logging and replanted with Mahogany, with a felling cycle of 25 years.

In 2014, no timber harvesting was planned nor implemented within the FCFR. CSFI thus focused on existing gaps in the forest bearing no trees over 20 cm dbh. Within the reserve, the following categories of these gaps are present:

| Category of gap | Suitability for reforestation |
|---|---|
| Natural open zones (swamps, savannas, etc.) | Unsuitable locations for the planting of target timber species |
| Natural gaps in forest cover due to wind damage, mortality etc. | Suitable for reforestation, presently harboring only dominant secondary forest and pioneer plants |
| Man-made gaps created by selective timber harvesting during previous logging. | Suitable for reforestation, presently harboring only dominant secondary forest and pioneer plants |
| Timber yards and gaps along the forest roads. | Less open, only moderately suited for reforestation (due to soil compaction, necessity for future timber yards, etc.) |
| Existing illegal agricultural and logging areas. | Very suitable reforestation locations, with low investment required. |


*Timber yard (Bacadillos)*


*Gap inside forest*


*Illegal agriculture*

Work undertaken in 2014 shows that re-opening of former large slash and burn areas covered in secondary vegetation is very labour intensive. Due to budget restrictions, it was decided to concentrate planting efforts in 2014 on gaps along the road, former timber yards and small, recently-opened agricultural areas.

### 5.3.2 Gap size and crown closure

20 gaps were opened within Freshwater Creek, all of which had an area of 500 $m^2$ to 1300 $m^2$. In comparison, gap plantations of Mahogany in Brazil have an average gap size of 91$m^2$ to 542 $m^2$ (257 $m^2$ average = 18m diameter) (*Planting Mahogany in canopy gaps created by*

*commercial harvesting, J.do C.A. Lopes, S.B. Jennings, N.M. Matni*). It is of interest for FCFR to compare results in relation to gap sizes, as too small a gap will impair proper growth and too large a gap will encourage strong competition with pioneer plants and the invasion of Mahogany pests such as the shoot borer. Conclusive results on ideal gap size should be realized within 5 years.

Gap size is measured from crown to crown (and not from trunk to trunk). During the planning phase, it is also important not to neglect treatment of adjacent crowns and canopy in general, as an increase in shade can seriously impede growth in young Mahoganies.

### *5.3.3 Thinning of surrounding forest stand*

*A gap in the forest where some trees still await removal to give light to young Mahoganies*

Thinning of existing forests in order to provide light to existing or planted young Mahoganies was not planned for 2014, however this technique could be implemented if Mahoganies get planted or young stands of Mahoganies should be discovered in old recovering gaps or agricultural areas.

### *5.3.4 Preparing the planting sites*

*Area before treatment*

*After treatment and ready to be planted*

Potential planting sites were inventoried, and their individual sizes were recorded. The existing vegetation, tree species, structure and the environment were also documented. Particular attention was paid to naturally regenerating young trees of valuable timber species, which were clearly marked as such.

### 5.3.5 Mahogany planting

The planting pattern was adjusted to each planting site, depending on its size. Trees were planted in a triangular grid with distance between trees either 2 by 2 or 3 by 3 meters according to the size of the gap. The grid pattern itself is chosen to help locate trees when surrounding vegetation grows and needs to be cleared. The fairly dense planting pattern was chosen for the following reasons:

- Maximizing use of available resources, since clearing gaps is expensive
- In light of a lack of knowledge on tree mortality and damage in the first 10 years, higher density planting is precautionary
- Potential for greater selection of quality trees (positive selection)
- Enhanced amount of data to evaluate success in reforestation over the next few years

The field team was divided in two crews, each consisting of 4-5 forest workers and a CSFI Ranger acting as group leader. All steps of the project were discussed with all team members before implementation. Machetes were used to clear the planting areas of vegetation, with the exception of any valuable naturally regenerating timber tree. The resulting biomass, together with any dead wood found was piled, and not burned. Piling and mulching are preferable for ecological reasons and because the decaying material will over the years turn into valuable substrate. One team member working the chainsaw shifted between teams to fell larger or dead trees, whenever needed.

*Right: team receiving instructions for clearing*

*Training on planting techniques*

*Planting*

*Teamwork*

To organize the planting, a grid made of ropes was first created, as most planters were not experienced forest workers. Planting occurred in June, 2014. In total 1100 Mahoganies, produced at Shipstern Conservation and Management Area were planted in the gaps, with an average age of 4 months and with a height ranging from 15 to 40 centimeters. Mahogany seedlings were either grown in “quickpots” or in larger plastic bags, and were put in the ground in a hole dug with a hoe. As an experiment, 100 young Mahoganies with bare roots immersed in mud were also planted.

### *5.3.6 Natural regeneration of timber trees*

*Esther and Gabriel mapping and measuring Mahoganies*

*Bakche and a 4 meter high Mahogany Tree*

*Pascal measures a young Mahogany*

As a preliminary and tentative conclusion, it appears that timber species in the forests of FCFR have a fair potential for natural regeneration, in cases where mother trees are still present. This natural regeneration could be enhanced by various silvicultural techniques, and would increase productivity greatly. However, the scope of these techniques should be carefully balanced so as not to disturb the functional integrity of natural forests.

**Natural regeneration of Mahogany on a larger scale**

During seed prospecting missions, a site showing regeneration of Mahogany on a large scale was discovered. This relatively lightly covered forest stand included approximately 20 Mahogany trees with a dbh over 20cm, all seed bearing. On this same site, more than 200 young Mahogany trees were found. It is interesting to note that Mahogany, although being a very light demanding species, can regenerate itself within forest systems that are not completely open.

Site 15 before maintenance After maintenance. Each pole is one of 63 Mahoganies

Another example was found along one of the forest roads in Block 3: "Planting site 15_2014" has demonstrated this regeneration of Mahogany in a semi-closed forest system. In a fairly large gap of 30 meters, probably opened during the last concession 5-10 years ago, 63 young Mahogany trees were inventoried, with a height ranging from 15 to 50 cm. These trees were all overgrown by a dense 3m high secondary re-growth, and would mostly not have reached maturity because of strong competition from other species. After the clearing of the gap (see pictures above), trees were marked with a wooden pole and a number. As a comparative experiment, 12 other Mahogany trees were planted in the same area.

### 5.3.7 Documentation of stand establishment


Preparing poles Numbering Numbers Measurement

All planting sites were duly documented following clear protocols. Planting sites themselves were described before and after intervention, and photographed. All trees planted or occurring naturally were measured and mapped. Last but not least, total labor time per site was recorded. Each tree planted was marked by a 1 meter high wooden pole and a numbered flagging tape, in order to keep track of trees until a follow-up visit.

#### 5.3.8 Planting site maintenance

*Crippled terminal shoot by shoot borer infestation*

*Liane braid*

*Damage by lianas on Mahogany*

Increased light incidence in gaps and the success of vines and lianas under such conditions have long been seen as a plague by tropical foresters. There is no other option but to remove vines periodically when reforesting open areas, not only from planted trees, but also trees regenerating naturally. This enhances the stability, growth and quality of future trees.

Artificially and naturally established stocks of Mahogany trees are also under threat from pests, especially in the early years of growth. Various species of grasshoppers and leaf-cutter ants had attacked some of the trees planted in 2014 within a few weeks of their planting. With about 5% loss, the damage is currently within reasonable limits, but the situation must be checked carefully in the next few years. Damage by mammals such as rodents or deer has not been observed but could be a risk.

The Mahogany shoot-borer (*Hypsipyla grandella*) is one of the most common and influential forest pests in the reforestation of Mahogany and Spanish Cedar. The shoot-borer, as its name reveals, attacks developing twigs in young trees aged 1-5 years. Shoot borers can cause very serious damage in large-scale plantations. One of the main attractions of working within gaps in a closed forest system is that this approach may prevent the development of large shoot-borer populations and their spread.

#### 5.3.9 Intermediate check on reforestation success, July 2014

An unusually persistent drought in July 2014, 4-5 weeks after planting, necessitated an early check on 50% of the planting sites. Around 15% of planted trees had died, most probably due to lack of water. This was most evident on one site with shallower soils and high solar radiation. Interestingly, among the dead plants were mostly those in quickpots and or planted with their roots bare. Plants in bags clearly had the best success. Competing species had already reached the height of planted trees, while lianas had already covered some of the trees. This was cause for some concern.

### 5.3.10 Care and maintenance of the reforestation plots

The dry period in June / July 2014 and the resulting mortality of young trees, although not dramatic, show that climatic conditions may play an important role in the course of the project, and be a risk factor. In addition to optimal stand conditions and gap size, which still need to be identified properly, there are various solutions to mitigate risks:

- Planting during the real rainy season from September to December. This however depends on access, as current roads can become impassable during heavy rains.

- Periodic irrigation of plantations, although this is very costly and labor intensive.

It is quite clear that to reduce mortality due to lack of light, planting sites will have to be maintained in the initial years after planting. Within years 1-3, Mahoganies that did not survive can be replaced, in order to maintain initial stem numbers at a high level.

Lack of experience at this stage allows us only to estimate correct intervals between maintenance operations. These estimates will be refined as we gain experience, but for the time being the project will use the following assumptions:

- First maintenance approximately 4-6 months after planting
- Second maintenance approximately 10-12 months after planting
- Subsequently, one maintenance visit per year for the first 5 years.
- A first selection of the most promising trees can be scheduled between the 5$^{th}$ and the 10$^{th}$ year, with other competing trees thinned.
- Crown thinning could be implemented between year 10 and year 20, as required
- Specific treatments such as pruning still need to be evaluated

### 5.3.11 Further forest enhancement measures

*The crown of this beautiful Mahogany (left) is strongly suppressed by a competition tree*

*The competition tree of this Mahogany was girdled*

*Removal of vines around a Mahogany*

Due to budget restrictions in 2014, only a few forest enhancement measures were implemented. These were:

- Girdling of competition trees of Mahogany (in about 4 trees)
- Cutting of lianas around future trees (about 20 trees)

The following silvicultural treatments will be evaluated as they become relevant:

- Pre-commercial and thinning of planting sites and or sites with high natural regeneration
- Crown thinning
- Rejuvenation treatments of various trees, including seed trees

*While working throughout FCFR, overgrown forest roads of obvious importance to the project were gradually reopened.*

# 6 Forest plant production

*Mahogany seedbed at CSFI tree nursery*

## 6.1 Baseline

A core objective of the FCFR forest management project is the artificial enrichment of existing forest or deforested areas with valuable timber tree species. In this first year, we focused our efforts on the production of the two most valuable tree species, i.e. Mahogany and Spanish Cedar. In subsequent years, other tree and palm species will be evaluated and potentially produced.

For the production of Mahogany and Spanish Cedar, limited information was available, especially regarding production in Belize. Data of interest includes phenology, planting systems, growth rate, mortality and production costs. In the past few years, CSFI has been producing several hundred Mahogany trees. This was not scientifically documented, but did allow for practical experience benefitting the staff.

## 6.2 Objectives forest plant production 2014

- Expansion of the nursery at Shipstern headquarters for the production of 10,000 forest plants.
- Production of 5`000 Mahogany and 1`000 Spanish Cedar with different container systems
- Analyses of growing rate, mortality and production cost

## 6.3 Implementation

### *6.3.1 Mahogany seed harvest*


*Instruction*


*Application*


*Problem. solving*


*Rich harvest*

At the beginning of the project in early 2014, only five seed-bearing Mahoganies were known to FCFR, and as to when exactly their seed capsules were ripe was unfortunately not recorded.

Between February 3$^{rd}$ and February 6$^{th}$, and despite horrendous road conditions due to a belated rainy season, 243 Mahogany seed capsules were harvested from these five trees using long rope climbing techniques.

The Mahogany harvest within the Reserve proved not only rather poor, but also very expensive. Towards the end of the harvest operation, a local farmer showed CSFI staff the Mahogany trees on his property, which were all producing more than a hundred fruit capsules per tree. The farmer allowed CSFI to collect the capsules of the best phenotypes.

Each harvest tree was recorded using GPS, measured, assessed, and given an individual identification number. This reference number was also given to any descendants grown the tree nursery.

*Inventory of Mahogany seed harvest trees 2014*

| Identification number (ID) | Tree species | DBH in cm | Fruit capsules | Date of harvest | Quality | Location |
|---|---|---|---|---|---|---|
| SM1 | *Swietenia macrophylla* | 31.8 | 5 | 03.Feb.2014 | nice | FCFR |
| SM2 | *Swietenia macrophylla* | 29.9 | 4 | 03.Feb.2014 | nice | FCFR |
| SM3 | *Swietenia macrophylla* | 34.4 | 1 | 03.Feb.2014 | nice | FCFR |
| SM4 | *Swietenia macrophylla* | 41.1 | 24 | 05.Feb.2014 | fair | FCFR |
| SM5 | *Swietenia macrophylla* | 31.2 | 6 | 05.Feb.2014 | nice | FCFR |
| SM6 | *Swietenia macrophylla* | 29,0 | 98 | 06.Feb.2014 | fair | Private |
| SM7 | *Swietenia macrophylla* | 26,1 | 23 | 06.Feb.2014 | good | Private |
| SM8 | *Swietenia macrophylla* | 29,9 | 82 | 06.Feb.2014 | fair | Private |
| Total Fruit capsules | | | 243 | Av. 55 seeds/capsule | ca. 13`365 Seeds | |

In tree production, it is of importance to select mother trees properly, in order to ensure that only the best phenotypic profiles are selected. This improves the changes of descendants inheriting traits of interest, such as vigor and trunk stature. Seeds were therefore harvested from large, tall, straight trees that had clearly had an advantage over others during their growth.

In the long term, it is also important that seeds come from as many mother trees as possible in order to ensure genetic diversity. Mother trees should be of local stock as far as possible. As Mahoganies grow in a relatively large variety of habitats in very variable conditions, phenotypes are bound to be linked to their habitat. This should be taken into account even on a regional scale. Other phenotypes could eventually be tested, but this is not a priority at present.

*Harvest of Mahogany fruit capsules. Fruit capsules normally open in February while still on the mother tree. Each capsule releases about 55 winged seeds.*

#### 6.3.1.1 Conclusions: Seed harvest

The 2014 experience with gathering Mahogany seedlings points to the following conclusions :

- More seed bearing Mahoganies of good stock should be searched for within FCFR, in order to prioritize local phenotypes.
- More phenological data must be acquired, foremost on capsule maturity vs. climate.
- The safety aspects of seed harvesting must be analyzed and when needed increased.
- Staff should regularly be trained for seed harvesting techniques.
- Proper equipment is needed, for instance for tree-climbing.

### 6.3.2 Seeds

*Seeds were sorted according to mother trees*

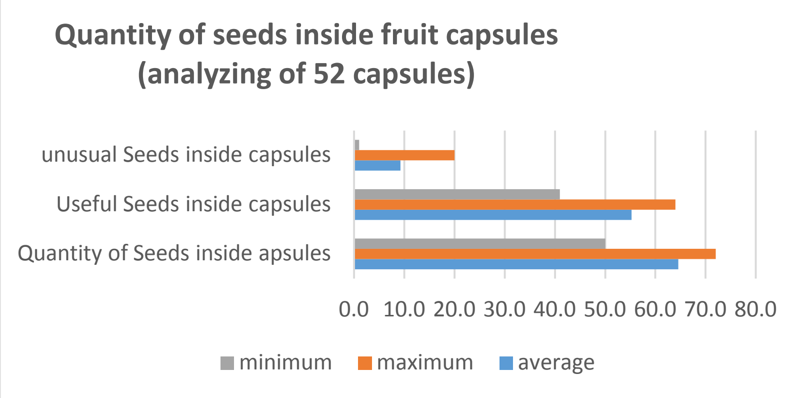
*Analysis and recording of seed data*

*A large difference in capsule size was found among various mother trees*

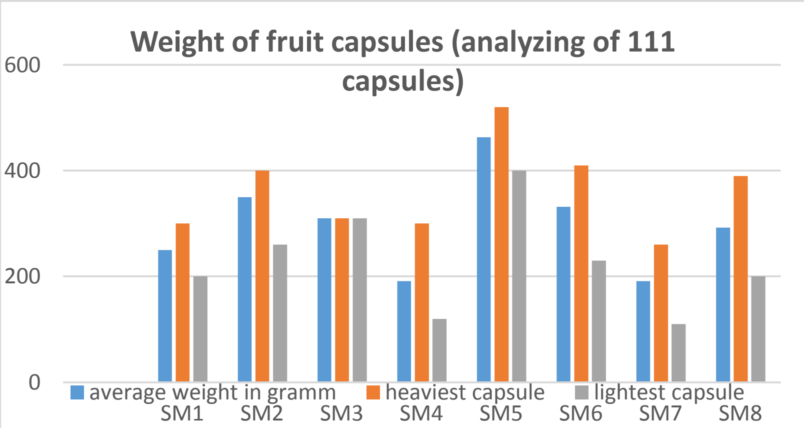
*There are between 50 and 70 wind-dispersed seeds in each fruit capsule*

Mother trees showed a great variation in capsule size. The reasons for this can only be hypothesized, but most certainly have to do with incomplete development processes, variation in maturity, tree vitality, crown competition, phenotypic characteristics and/or local environment. All 243 capsules were weighed and the number of seeds in 55 of them was recorded.

The capsules were left to ripen in the sun for five days following the harvest. The capsules opened naturally and seeds could easily be collected from their protected shell. The seeds from each single mother tree were kept separate, and then either dried in a well-ventilated and shady place, or planted immediately. Excess seeds were dried and stored in glass containers in a cool place. The 243 capsules contained approximately 13,300 seeds in total.




*Each capsule contained 50 to 72 seeds, of which 1 to 20 were not mature and discarded. The average of viable seeds per capsule is thus 55.*




*The weight of the capsules can vary greatly. For example, the capsules of mother-tree SM4 are on average less than half the weight of the capsules of mother-tree SM5.*

*The fruit capsules and seeds of Spanish cedar are similar to those of Mahogany, but significantly smaller.*

### 6.3.3 Spanish Cedar seed harvest

With regard to Spanish Cedar (Meliaceae: *Cedrela odorata*), not a single seed-producing tree was found inside FCFR. Seeds were thus collected on four old specimens growing on the southern boundary of Shipstern Conservation and Management Area.

### 6.3.4 Expansion of the SCMA tree nursery

*Production area with seedbeds*

*Testing area with propagation tables*

In 2014, the tree nursery at Shipstern headquarters was enlarged for the production of 10'000 forestry plants. The tree nursery was divided into a production area (PA) and a testing area (TA). Each area was covered by a roof construction consisting of local round logs and shading nets. The shading nets protect the seedlings from excessive exposure to solar radiation and heavy rain. A sprinkler system was installed for irrigation.

The existing concrete seedbeds were renovated and prepared for planting. The soil was sieved and enriched with humus. In the testing area, wooden propagation tables were built at ideal working height.

### 6.3.5 Plant production

#### 6.3.5.1 Preparation of the seeds

According to local tradition and experience, the seed wings are ideally broken off before planting. In nature, the wings remain on the seeds during germination. The difference in germination success between the two methods was not tested. However, the results of the standard tests prove that Mahogany seeds germination is faster and more successful if the seeds are soaked for approximately 6 to 12 hours prior to planting.

#### 6.3.5.2 Plant substrates

Finding a suitable substrate in the SCMA region at a reasonable price proved to be a key challenge of the tree nursery project. Ideally for the propagation of forestry plants, forest and farming soil rich in nutrients is sieved and mixed with peat or composted humus in a relation of 3 to 2. For logistic and financial reasons, it was not possible to order a truckload of ideal regional plant substrate. Substrate rich in humus is generally rare in the region and the demand is high, especially in agriculture. Today, only CSFI and a handful of locals practice composting, although the potential is enormous.

Plant production and tests thus had to be improvised. At the SCMA Headquarters there was a remaining stock of soil. This soil was sieved and mixed in a relation of 4 to 1 with different composted humus soils. We attempted to extract soil from the surrounding forests, but shallow soils, numerous roots, the amount of work involved and the distance to cover clearly showed this option was not feasible. At first, compost soil was bought from an agricultural supplier. However, cost for both soil and delivery were very high. In addition, the environmental balance was very negative, the compost soil being actually imported from the

USA. In a second phase, composted sugar cane residuals were used. This material can be picked up free of charge at the sugar factory in Orange Walk. As the fermentation process seemed not yet complete, it was only mixed into the soil in a relation of 1 to 4.

In the test series at the tree nursery experiments were made using other substrate mixes.

#### *6.3.5.3 Plant containers*

The seeds were sown in different containers allowing a comparison of economic factors and growth patterns.

**Seedbeds**

Part of the mahoganies was propagated in seedbeds, a typical method in many tree nurseries. Germination and growth rates are very high with this method, which is does not take excessive space. However, transplanting shock, high mortality after transferring into bags and high workload involved are clearly disadvantages. A test planting of 100 mahoganies with naked roots was unsuccessful due probably to a particularly dry period at the time of planting, but possibly also excessive transplanting shock.

**Plastic bags**

Plastic bags of different sizes are often used locally for the production of forestry plants, and can be readily acquired in Orange Walk and Chetumal. The filling of bags with substrate represents the bulk of the work load for this method, however several ways to optimize or even automate this work process could be applied. The planting and rearing of seeds, the maintenance of the tree nursery, the handling of young trees and transport to the planting sites proved to be successful. However, when using plastic bags only few plants can be handled at a time while bags can often only be used once, which is environmentally unfriendly.

Attempts to remove the young trees without cutting apart the bags before planting often resulted in damage to the root ball and fine roots.

**Quickpot trays**

Quickpot trays are widely used in forestry nurseries and professional reforestations projects around the globe. The trays are easy to fill with substrate and seeds. The compact trays containing several plants are very space-saving, which makes the handling in the tree nursery and at the planting sites very easy. The rooting activity of the root ball is very intense due to the cutting of the aerial roots. In the field, the root ball is easily extracted out of the tray and the tray can be used several times if handled carefully.

During the project year 2014, only Quickpot trays with a small root volume were readily available. Unfortunately, all attempts to order trays with a larger root volume from local agricultural providers failed, as did attempts to find them in Chetumal.

**Conclusion: plant container**

- Because of the planting shock, high mortality and work load, replanting young trees from seedbeds into bags is not very successful.
- Bags as a system are practical. A more economic solution should be found for the filling process. The ecological balance is not ideal.
- Large Quickpots, helping to avoid transplant into larger containers, would allow for the production of large quantities of trees and make handling easier.

#### *6.3.5.4 Planting of seeds*

After having been soaked and having their wings removed, seeds were planted with the base of the removed wing facing upwards. A planting hole 5cm deep and 2cm wide was drilled into the substrate with a dibber. Single seeds were placed in each hole and pressed down gently. As such, the wing base was left protruding from the substrate's surface while the actual seed body was enclosed in the soil.

The much smaller seeds of the Spanish cedar were processed in the same manner, but more carefully. These seeds were not soaked and the seed wings were not removed.

#### *6.3.5.5 Transplanting seedlings into larger containers*

Once they had reached a height of 15- 20cm the Mahogany seedlings were removed from seedbeds and planted into plastic bags. The seedlings were lifted with a spade, carefully removed, immediately planted into bags and watered as quickly as possible. The workload, the intense planting shock and the high mortality were the negative factors in this stage of the process.

The transplanting of Quickpot seedlings into larger bags was generally very successful. The seedlings rooted well and the entire root ball could be removed from the tray easily and refitted into the bags without destroying the fine roots. There was no planting shock and no mortality. In the future Quickpots with a larger root volume should be used so that the entire transplanting process can be omitted.

#### *6.3.5.6 Maintenance and care of the tree nursery*

Daily care consisted of optimal irrigation and an optical screening of seedlings for plant pests, mortality or symptoms of disease. Plant litter and fruit from surrounding trees were removed regularly. The workload for the maintenance of the nursery with 10’000 forestry plants amounts to an average of only one to two hours a day, providing an irrigation system is at hand.

#### *6.3.5.7 Transport of the forestry plants*

The four hour transport of plants from tree nursery to the project area proved to have a negative impact. Forestry plants are very fragile with regards to airstream and direct solar radiation. The plants were watered before transportation. Although it was attempted to protect the plants with tarpaulins, some of them were damaged during transport. Only a modest amount of plants could be transported on each journey, due to limited loading capacity of available vehicles, a problem that had been foreseen at the onset of the project. A new nursery at FCFR has been built at the end of 2014 and will be fully operational in 2015, which will help alleviate the problem.

#### *6.3.5.8 Conclusion propagation of forestry plants*

- The annual planning should define the number of trees of each species to be produced.
- The necessary resources must be organised well in advance and in sufficient quantity.
- Composting of organic waste at CSFI’s headquarters and at Santa Marta should be initiated.
- Large Quickpot trays must be found and acquired.
- Work processes, responsibilities and project organisation need to be optimised.

## 6.4 Research on Mahogany production

### 6.4.1 Standardised tests on the germination potential of collected seeds

*Tests on the germination capacity of Mahogany seeds*

The germination capacity of Mahogany seeds was studied using standardised tests. 20 Mahogany seeds of given trees were placed in styrofoam containers sealed with cellophane and were observed until they germinated. The bottom of each styrofoam container was lined with absorbent paper, and seeds were moistened daily. The test series were kept in a shady place with aeration. They were checked twice a day and kept humid.

Soaking seeds before planting has a positive effect on the development of many tree species. The positive effect on the time span needed to germination was also confirmed for Mahogany. Half of the seeds in the standardised tests were soaked for approximately 12 hours in a bowl of water. Soaked Mahogany seeds germinated after 20 days on average, while seeds which had not been soaked took on average 13 more days to germinate.

The germination capacity of tested seeds, at approximately 93%, is very high and confirms good seed quality. With time, however, this germination capacity is bound to diminish. The soaking of seeds proved to have influence only on germination speed, but not capacity.

| Seed harvesting tree | Number of days until germination of the 1. seeds | Number of seeds | Total germinated seeds | Germination capacity in percent |
|---|---|---|---|---|
| SHNR | 21 | 20 | 17 | 85 |
| FWCF Sm4 | 16 | 23 | 22 | 96 |
| FWCF Sm8 | 22 | 25 | 23 | 92 |
| **Average soaked seeds** | **20** | **68** | **62** | **91** |
| SHNR | 38 | 20 | 18 | 90 |
| FWCF Sm4 | 28 | 23 | 21 | 91 |
| FWCF Sm8 | 32 | 25 | 25 | 100 |
| **Average non soaked seeds** | **33** | **68** | **64** | **94** |

### 6.4.2 Test series in the testing area (TA)


*Each seedling in the study was individually labelled*

In our testing area, 799 Mahogany and 620 cedar seeds were planted in Quickpot trays and other pots (cups) in various types of substrate. Each Quickpot tray was planted with 50 seeds from a given mother tree. In each tray, 10 trees were measured weekly and their development was documented. The germination time and the germination success were recorded for all seeds. The data were collected from the 14th of February 2014 onwards.

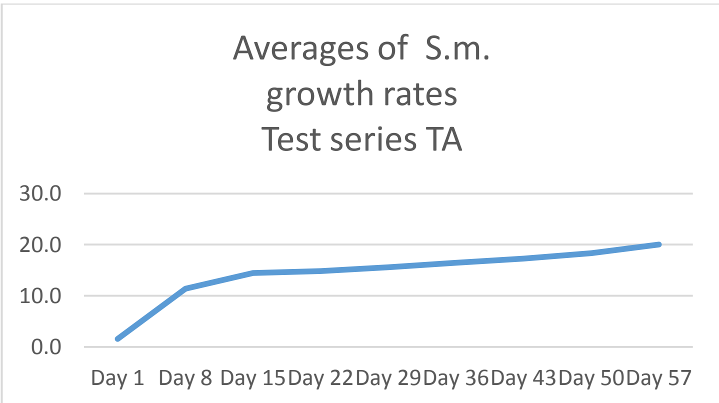
**Test series: Germination and rearing success of mahoganies (TA)**

| Test series | Number of seeds | Germinated seeds | Germination success in percent | Days until germination of first seeds | Failed seedlings | Mortality of seedlings in percent | Total Mahogany seedlings | Rearing success in percent |
|---|---|---|---|---|---|---|---|---|
| Average Quickpot series | 590 | 527 | 89 % | 22 | 74 | 14 % | 453 | 77 % |
| Total and average cups | 209 | 156 | 75 % | 23 | 12 | 7 % | 144 | 69 % |

Germination success of almost 90% is very high, as is rearing success with 77%. The test series using cups is listed separately, as these tests were made with different substrates, distorting the data.

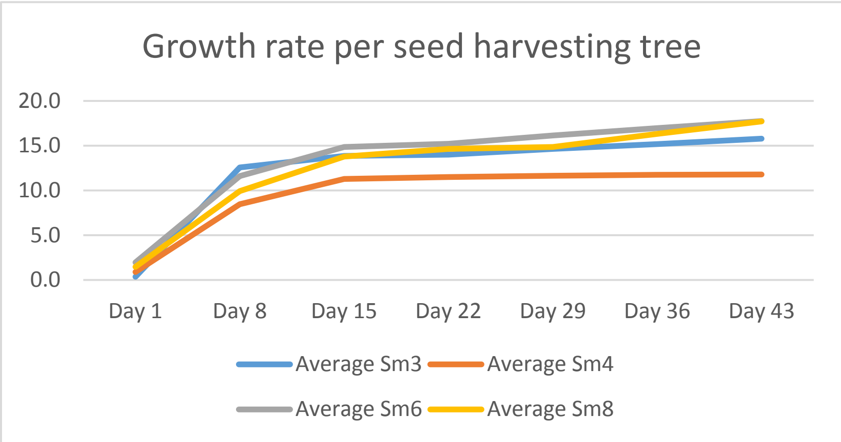
**Growth tests with Mahogany seedlings TA**

Each Quickplot tray was planted with 50 seeds of a given mother tree. 5 trees per tray were measured weekly and documented. Over a period of 57 days (8 weeks) the growth of 63 test plants was measured. All data sets show a very strong initial growth of 10cm within the first week, an average of 1.4cm per day !



The growth curve then flattens off and the young Mahogany trees continue to grow approximately one centimetre per week. The root ball volume in Quickpot trays started limiting young trees after 5 weeks. For this reason, data towards the end of the series are probably distorted towards the lower end.

| Days | Day 1 | Day 8 | Day 15 | Day 22 | Day 29 | Day 36 | Day 43 | Day 50 | Day 57 |
|---|---|---|---|---|---|---|---|---|---|
| Average mean values in cm | 1,6 | 11,4 | 14,5 | 14,8 | 15,6 | 16,5 | 17,3 | 18,4 | 20,0 |




Results show that growth rates of seedlings of individual mother trees vary despite identical growth conditions. Mother tree Sm4 with the lowest growth rate also produced the smallest fruit capsules and seeds.

### 6.4.3 Test series in the production area (PA)

#### 6.4.3.1 Test series: germination and rearing success of mahoganies

In our production zone, a total of 5013 Mahogany seeds were planted in seedbeds, plastic bags and Quickpot trays and sorted according to mother tree. The germination time of the first seeds and the germination and rearing success of all seeds were registered. The following data was collected between from the 20th of February 2014 onwards.

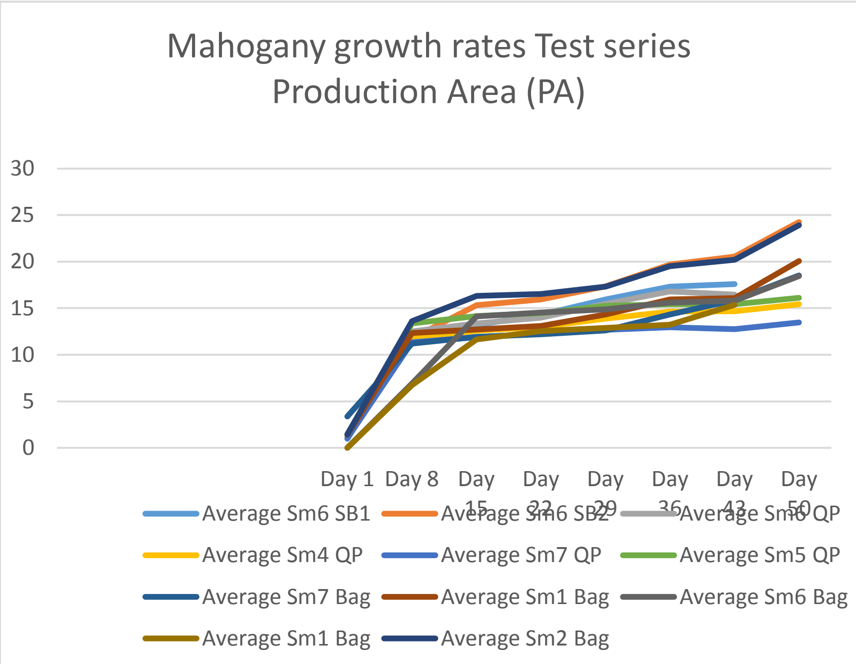
| Plant container | Number of seeds | Germinated seeds | Germination success in percent | Day until germination of the first seeds | Failures | Mortality of seedlings in percent | Total Mahogany seedlings | Rearing success in percent |
|---|---|---|---|---|---|---|---|---|
| Plastic bags | 629 | 520 | 83 % | 24 | 19 | 4 % | 501 | 80 % |
| Seedbed 1 & 2 | 2584 | 2327 | 90 % | 21 | 228 | 10 % | 2099 | 81 % |
| Quickpots | 1800 | 1384 | 77 % | 21 | 108 | 8 % | 1276 | 71 % |
| **Total PA** | **5013** | **4231** | **84 %** | **22** | **355** | **8 %** | **3876** | **77 %** |

In the production area, germination success was also very high, at almost 85%, as was the rearing success at 77%. Mortality was due partly to plant pests (mainly grasshoppers) and partly to an as yet unknown reason.

### 6.4.3.2 Growth studies of Mahogany seedlings

In the production area, growth of seedlings in various plant containers was analysed for a period of 50 days. 108 seedlings of various mother trees in seedbeds, plastic bags and Quickpots were studied separately. Data was collected weekly.

| Test series | Day 1 | Day 8 | Day 15 | Day 22 | Day 29 | Day 36 | Day 43 | Day 50 |
|---|---|---|---|---|---|---|---|---|
| Average Sm6 SB1 | 1,0 | 12,1 | 13,2 | 14,3 | 15,9 | 17,3 | 17,6 | |
| Average Sm6 SB2 | 1,4 | 11,7 | 15,3 | 15,9 | 17,4 | 19,7 | 20,6 | 24,3 |
| Average Sm6 QP | 1,3 | 12,5 | 13,4 | 14,0 | 15,5 | 16,8 | 16,5 | |
| Average Sm4 QP | 1,1 | 11,8 | 12,6 | 13,0 | 13,9 | 14,6 | 14,7 | 15,4 |
| Average Sm7 QP | 1,1 | 11,3 | 11,9 | 12,3 | 12,7 | 12,9 | 12,8 | 13,5 |
| Average Sm5 QP | 1,5 | 13,4 | 14,2 | 14,5 | 15,3 | 15,4 | 15,4 | 16,1 |
| Average Sm7 Bag | 3,4 | 11,2 | 11,9 | 12,2 | 12,6 | 14,3 | 15,9 | 18,5 |
| Average Sm1 Bag | 1,4 | 12,3 | 12,7 | 13,1 | 14,3 | 15,9 | 16,1 | 20,1 |
| Average Sm6 Bag | 0,0 | 6,9 | 14,1 | 14,6 | 14,9 | 15,6 | 15,8 | 18,5 |
| Average Sm1 Bag | 0,0 | 6,8 | 11,7 | 12,5 | 12,9 | 13,2 | 15,4 | |
| Average Sm2 Bag | 1,4 | 13,6 | 16,3 | 16,5 | 17,3 | 19,5 | 20,2 | 23,9 |




Similar to what was observed in the testing area, a fast initial growth of seedlings occurred, with growth curves flattening strongly thereafter. The development of seeds of trees Sm6 in a seedbed and Sm2 in bags was by far the fastest. Growth in Quickpots was slowest due to the limited volume of root balls. Data show that Mahogany seedlings can reach a height of 25cm in 7 weeks.

Seedlings from mother trees with the smallest and lightest seedpods also had the lowest growth rates (Sm4 und Sm7). However, these were all planted in Quickpots and may have grown faster in containers with a larger root volume.

*Measurement of Cedrela seedlings*

#### 6.4.4 Maximum height of Mahogany seedlings

The growth record was held by a Mahogany seedling of mother tree Sm7, which reached 52cm in 142 days.
A repeated measurement of 65 of the largest Mahogany trees on the 3rd of August 2014 yielded an average height of 40cm.

Ideally, young trees should have reached a height of 30 to 50cm before being planted into the forest. During the 2014 Mahogany production year, it was demonstrated that trees can reach this height within 20 weeks. This time lapse coincides ideally with the beginning of the rainy season, which is also the perfect moment for reforestation in the field. In the future, forestry projects can thus be planned in a one-year cycle. Seed harvesting (February), nursery (March to July), Reforestation (June to September)

***Image on the right:*** *Esther Aemisegger, responsible for the CSFI Mahogany production project 2014, with a young Mahogany. The seeds were harvested on the 29th of January 2014 and the seedlings had reached a height of 50 cm within 20 weeks!*

#### 6.4.5 Use of fertilizer in Mahogany production

Various experts, specialized literature and scientific publications advise against the use of synthetic fertilizer in forestry plant production during the germination period. Organic fertilizers are used in some tree nurseries in limited quantities and at low dosage.

For environmental reasons, the project management decided not to test the use of synthetic fertilizers during the production year 2014. Various organic fertilizers (alkali, egg shells etc.) were tested. Unfortunately, data series are too small to show any tendencies.

The supply of plant substrate should receive much more consideration from the project management. An optimal nutrient-rich soil combined with biologically composted humus would make an ideal basis for the production of forestry plants.

The growth rates of the individual trees at planting sites will be measured over the next decades. Fertilizing could have a positive effect on these growth rates. In many countries this practice is applied, mainly in forestry plantations. In countries with severe forestry laws, for example Switzerland, such methods are forbidden as a forbidden. From a silvicultural point of view, light conditions, maintenance and care of reforested areas will be the most important factors for successful growth in the first five years. Thereafter, the application of fertilizers could have a positive effect on the growth of the trees, but this needs to be tested. Ideally, this project would rather make use of natural and biological silviculture techniques without using fertilizers in FCFR.

### *6.4.6 Conclusion of the study on Mahogany production*

- Seeds soaked for 12 hours germinate on average 10 days earlier than non-soaked seeds.
- Soaked seeds germinate after 20 days on average, the seedlings becoming visible after 22 days.
- The high germination rate of the Mahogany seeds (90%) and the high rearing success (80%, just under 10% mortality) were surprising.
- In the first week, seedlings grow 1.4cm per day on average and more than 10cm in total
- In the following weeks, growth rates decrease and seedlings continue growing at a rate of one centimetre per week.
- In the 5 week growth period after germination, seedlings reach an average height of 19cm.
- Within 20 weeks the Mahogany seedlings reach an average height of 40cm. The record height of a seedling was 52cm.
- Mahogany seeds which are harvested at the beginning of February produce seedlings with an average height of 30 to 50 cm within 5 months, i.e. by July. This plant size is ideal for reforestation during the rainy season between June and December.
- The limited root ball size of Quickpots has a negative impact on growth.
- Availability of plant substrate and composting should both be considered in more details.

# 7 Training CSFI Team

*Field training on identifying tree species*

The CSFI team was trained continuously in 2014. Before each new step in the project, objectives and security issues were discussed and evaluated jointly by the whole team.



*Theory* *Practice* *Group work*

At the end of June 2014, a three-day training recapitulating the forest management project was carried out with the entire CSFI ranger team. All field activities were discussed in detail, while practical exercises were done in small groups. The training also gave an overview of the following:

- Short lecture on forestry in Switzerland and Europe
- Overview of FSC forest management in Switzerland, and an overview of practices in Belize and some other parts of the world
- Review of practices such as seed harvest, tree nursery and production
- Review of afforestation as well as planting techniques and records
- Forest inventory techniques
- IT Data Management
- GPS and GIS Basics and Applications
- Safety Workshop

Some members of the team also underwent training offered by the Government of Belize on topics such as forest management, forest inventory, wildlife and water monitoring, and fire management.

# 8 Organizational aspects of field work in 2014



*Camp life*

The implementation of the forest management project was a relatively new endeavour for CSFI's team, and many aspects of it had to be built up, or sometimes even creatively improvised, also in view of the limited resources at hand. In parallel to these new activities, CSFI's team also had to carry out standard surveillance duties at Shipstern Conservation and Management Area and Honey Camp National Park. As far as feasible, synergy among individual tasks was sought, but this was not always successful and created, at times, some confusion.

Early on in the work, the sheer distance between CSFI's headquarters at Shipstern and Freshwater Creek turned out to be a challenge and very resource-demanding in time, fuel and vehicles. As an example, for a total of five days of field work, 1.5 day was lost on transportation, camp installation and resupplying.

The initial 2014 test phase of the project has clearly shown that it will be essential, in the near future, to have headquarters for FCFR close to the Reserve itself. In the interim, CSFI management decided to seek housing in the community of Santa Marta, just south of Freshwater Creek. This has already proven to make work practical, and saves significant resources.

# 9 Forest management strategy and planning


**The data collected in 2014 provide a first step towards the development of a solid forest management strategy for Freshwater Creek Forest Reserve. A second phase in this development should include a thorough study of various sustainable forestry management and silviculture tools including planting, pre-commercial and commercial thinning (PCT & CT), reduced-impact logging (RIL) as well as the sustainable harvest of Sabal palm leaves and other non-timber product. Thought should be given as to how these techniques could be applied to FCFR. Thereafter, field trials should be carried out, ideally from 2016 onwards.**

**Overall, it is CSFI's goal to keep its strategy for FCFR simple, based on tested tools and techniques, to be repeated in cycles, implemented on a step-by-step approach based on local economic realities.**

**Key data pertaining to species composition, stock and forest growth will eventually be extended to the other blocks of FCFR in order to give a final projection of what FCFR entails.**

**Providing financial resources become available, CSFI will also analyze the existing biomass and the $CO_2$ storage potential for FCFR, using a random sampling grid. This will allow FCFR to seek integration into national REDD+ programs when the time comes.**

**The national forest legislation of Belize as well as requirements for FSC certification when harvest begins will form the framework for sustainable forest management. It is therefore essential that forest inventory data, forestry techniques, High Conservation Value areas, wildlife monitoring etc, be recorded from the very start of the project in order to be able to document sustainability in the long term.**

**The forests of the FCFR clearly have significant ecological, social and economic value, values that can be preserved while simultaneously allowing for a sustainable harvest of natural resources. If carried out carefully, and if long-term planning is implemented, FCFR has great potential to become a model for sustainable forestry and timber industry.**

# 10 Annexes (NB: provided as separate PDF or PPT documents)

## 10.1 Maps

## 10.2 PowerPoint Documentation “01. General Mapping”

## 10.3 PowerPoint Documentation “02. Forest Inventory”

## 10.4 PowerPoint Documentation “03. FCFR Silviculture Program 2014”

## 10.5 PowerPoint Documentation “04. Forest Plant production”

## 10.6 PowerPoint Documentation “05. Training”

## 10.7 PowerPoint Documentation “06. Law enforcement”

## 10.8 PowerPoint Documentation “07. Field Missions”

## 10.9 PowerPoint Documentation “08. CSFI Team 2014”