REGENERATION OF THREE IMPORTANT TIMBER SPECIES IN BOLIVIA

Case study in the Forest Management Unit hold by CINMA Ltda.

Bachelor Thesis, 2014

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Abstract

This report is the output of a Bachelor thesis study on the regeneration of three important timber species in the forest of Bajo Paragua in Bolivia. The study is comprised of research on existing literature with three separate field studies, performed in the Forest Management Unit (FMU) hold by CINMA ltda. The study was conducted in order to improve the understanding of the regeneration processes of three important timber species which are crucial for sustainable forest management. This study focuses on three commercial high value timber species; Cuta (*Apuleia leiocarpa*), Roble (*Amburana cearensis*) and Paquió (*Hymenaea courbaril*).The findings of this study can be used to adapt and implement new silvicultural treatments.

Regeneration of commercial tree species is of central importance to forest management to maintain sustainable timber yields (Schulze, 2008). In the polycyclic harvesting systems adapted in Bolivia, the second harvest (20–35 years after the first) will include trees already present in the stand at the time of the initial harvest. An analysis in form of a study of the Future Crop Trees (FCTs) of this already existing tree-composition is presented in section 1 of this report. With a sufficient abundance of FCTs, timber production can remain constant over the short term (2-3 cutting cycles). However, recovery of commercial populations through successful regeneration is critical to sustained production in successive harvest cycles (Schulze, 2008). Scarcity of both advanced and new commercial tree regeneration has been noted in many selectively logged forests in Bolivia. A regeneration study implemented by the company CINMA also shows the lack of sufficient regeneration of number of highly valuable and important timber species in their FMU (Cinma, 2014) (see ANNEX 1). To tackle this problem the company has started to implement enrichment plantings on a trial basis in their FMU. Seedlings have been planted on landings, skid-trails, in undisturbed forest and in forest which had suffered from forest fires. In Section 2 of this study, these plantations are evaluated in order to determine their efficiency and to make recommendations for the future. Enrichment planting might be appropriate in areas were natural regeneration is extremely low. However, costs seem to be too high to implement this silvicultural treatment as a standard procedure in Natural forest management in Bolivia (Pariona, et al., 2000) (Schulze, 2008). Alternatively, already existing regeneration of commercial timber species can be increased and supported by liberation treatments. Much of the regeneration of trees in a forest which is managed by selective logging activities will be recruited in logging gaps (Bazzaz, 1991). A study, presented in Section 3 of this report was conducted in order to determine whether enough natural regeneration of commercial timber species is present in logging gaps and skid-trails to justify the implementation of liberation treatments in the future.

The study shows that not for all three studied species enough FCTs are present to secure constant harvesting yields in the coming cutting-cycles. FCT of the species Cuta which were big enough to be harvested in the coming cutting-cycle showed a lower abundance per hectare than the harvested trees in 2014. The enrichment plantings performed best on landings, whereas in the forest which had suffered from forest fires, plantations were not very successful. The study of the regeneration in logging gaps and skid-trails resulted in the recognition that it depends very much on the forest type if liberation treatments are applicable or not. Of the species Cuta and Paquió, enough natural regeneration for liberation treatments could be shown in at least one forest type. Roble on the other hand showed too little regeneration in the study site to justify the application of liberation treatments. For this species and in areas with missing regeneration of other commercial tree species, enrichment plantings seem to be the only form to secure enough regeneration for future timber extraction.

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ABBREVIATIONS

AAA	Area Anual de Aprovechamiento (Logging compartment)
ABT	Autoridad de Fiscalización y Control Social de Bosque y Tierra (Forest and land authority)
ATE	Autorización Transitoria Especial (Special Temporary Authorization)
CINMA	Compañía Industrial Madera Ltda.
cm	Centimetres
DBH	Diameter at Breast Height
FCS	Forest Stewardship Council
FCT	Future Crop Tree
FMC	Forest Management Certification
FMU	Forest Management Unit
m	Meters
m.a.s.l	Meters above sea level
MCD	Minimum cutting diameter
PGMF	Plan Generales de Manejo Forestal (General Forest Management Plan)
POAF	Plan Operativo Anual Forestal (Annual Operating plan)
PSP	Permanent Sample Plot
RIL	Reduced Impact Logging

1 INTRODUCTION

Regeneration of commercially valuable trees species is crucial to the successful long-term management of humid tropical forests (Pariona, et al., 2002), (Park, et al., 2005). Only with adequate tree regeneration a sustainable wood production can be guaranteed. In managed tropical forests in Bolivia, commercial tree regeneration is generally sparse (Fredericksen, et al., 2002), (Fredericksen, et al., 2000), (Pariona, et al., 2002), (Park, et al., 2005). The rarity of high value commercial trees and species-specific environmental associations justify basing silviculture on the environmental requirements of individual species or species guilds (Pariona, et al., 2002).

2 LITERATURE REVIEW

2.1 NATURAL FOREST MANAGEMENT

There are many factors involved in the sustainability of forest management; one of the most important is probably the natural regeneration to ensure continuity of forest ecology. The success of natural regeneration is considered key to sustainable management of tropical forests. Ensuring the replacement of harvested trees has been a constant concern to ecologists and foresters in order to maintain the structure and composition of forests. (Pinto, et al., 2011), (Fredericksen, et al., 2001) Natural regeneration is the set of advanced regeneration, it is considered as the set of processes by which the forest is restored by natural means (Rollet, 1971). The term natural regeneration may refer to a process of natural replacement of trees. This process may be defined as the replacement of a set of trees that have reached their mature stage by new ones (Martínez, 1994).

Foresters must understand the entire life cycle of a tree, beginning with its reproduction, whether it happens by seed dispersion, sprouts, or a combination of both. It will be necessary to understand the rate of seed predation, germination and seedling survival in different conditions as well as the probability by which sprouts will later form commercially suitable trunks. In general, for all tree species, survival rates increase exponentially with size. It is not necessary to maintain all living trees in the forest, but rather only trees that can occupy the space available for growth (Fredericksen, et al., 2001).

In general, the diameter distribution of all tree individuals of a forest correspond to an inverted J-shape, which means that there are more individuals in the smaller categories than in the major categories (Mostacedo, et al., 2003). However, when an analysis of diameter distribution is made for each species, the distribution changes: the shade tolerant species tend to show an inverted J-shape while the distribution of shade-intolerant is bell-shaped ("normal" curve). (Pinto, et al., 2011)

A number of studies have shown that in Bolivian managed forests, many commercial tree species suffer from regeneration failures (Mostacedo, et al., 1990). These applies especially to forests where harvesting has been extremely selective, mostly confined to a few high value timber species. Little is known about the specific mechanisms that cause the failure of regeneration. Many native species are affected differently, which indicates that to solve the problem of regeneration we must treat each species separately (Mostacedo, et al., 2000). Regeneration success can also vary from one site to another. According to Mostacedo and Fredericksen (2000), the main causes of these problems in Bolivia are:

- Irregular or poor seed production
- High rates of seed predation or germination deficiency
- Attack of herbivores, pathogens or other diseases after germination
- Lack of large clearings with high light availability (for pioneer species)
- Excessive competition vines or other weeds regardless of gap size
- Slow natural growth rate of most hardwood timber species
- Lack of mineral soils for the establishment of seedlings
- Overexploitation

The causes of regeneration failure can be site specific and dependent on the ecology of a certain species. A species can fail to produce enough regrowth if seed production is irregular or low or if seeds or seedlings are heavily attacked by herbivores (see also chapter 4.3). Site specific causes can be natural or result from a certain management system. Overexploitation of species rich tropical forests can rapidly lead to the absence of sufficient trees for seed dispersion and result in the disappearance of a species in a certain area. Some species rely on a specific environment for their regeneration which might not be given through selective harvesting systems. Logging gaps might provide an adequate environment for one species but not favour the regeneration processes of another. Natural regeneration in gaps created by harvesting is generally low, despite the high levels of light penetration. Poor regeneration rates are in part due to soil compaction but to a large extent because up to 50 percent of the vegetative cover consists of vines. Shortly after the creation of a logging gap, vines rapidly colonize these environments characterized by high luminosity. They are using branches of fallen trees as support and eliminate the sunlight received by seedlings growing in the disturbed soil. When aiming for sustainable selective harvesting, the harvested trees need to be replaced by valuable species in the gaps created by this practice (Fredericksen, et al., 1998). Therefore, it might be necessary to liberate commercial regeneration or control non-commercial regeneration, by cutting or girdling to favour the succession of commercial species in canopy gaps (Fredericksen, et al., 2000). The size of the opening and the light availability do not only affect the plant establishment but also the survival rate and growth of saplings. In summary, establishing regeneration depends on the duration and quantity of light, and the distribution system and seed dispersal (Espinoza, 1991).

For a good natural regeneration seeds need to be exposed to the appropriate forest microenvironments. These differ in their light conditions, soil compaction and the presence of seedlings. Through harvesting activities a number of microenvironments like landings and skid-trail are created (Pinto, et al., 2011). These might be of high importance for the regeneration of some tree species.

There is little literature on the ecology of tree species regeneration in Bolivia. Pinto et al. (2011) assume that for a large amount of commercial species, regeneration is inadequate. There are serious problems in the regeneration of valuable species which need large openings and control of competing vegetation (Pinto, et al., 2011).

Fredericksen et al. (1998) have observed that the regeneration of commercial tree species after harvest is poor because it depends on the light and disturbance levels that individual trees do not provide. Low regeneration of commercial species in logging gaps is resulting in the rise of a group of different, less known species.

Different approaches are being suggested in order to support the regeneration of commercial timber species. It is possible, to rely on and support natural regeneration or to enrich the regeneration by planting saplings. In many cases the support of natural regeneration is more efficient and cost effective. Nonetheless it requires the presence of sufficient regeneration of the required tree species.

In 2009 CINMA ltda. has carried out an inventory of the whole FMU. The results from this forest inventory show that some important timber species show a very scares natural regeneration (see ANNEX 1). According to the results of the Forest inventory none of the three species of this study, Cuta, Paquió and Roble are regenerating well in the FMU. Cuta has been identified to have a regular amount of regeneration whereas Roble and Paquió were reported to have very scarce regeneration. With an average of only 2.4 individual trees per hectare with and DBH smaller 20 cm, Paquió showed the lowest regeneration of all commercially interesting tree species in FMU. The results for Roble showed an average of four individuals per hectare but a total absence of regeneration of trees smaller than ten meters in height.

2.2 SILVICULTURAL TREATMENTS

Silviculture, the main discipline of natural forest management, describes the cultivation of the forest (*silva* meaning "forest" and *cultura* meaning "cultivation") (Günther, et al., 2011). Silviculture is the practice of controlling the establishment of natural regeneration, tree growth, forest composition and how to reduce the impact the utilization (Pinto, et al., 2011). Through silviculture we create and maintain a kind of forest which best fulfils present and future human needs (Günther, et al., 2011). In his book Silviculture in the Tropics, Lamprecht (1986) cites Leibundgut: "Today, silviculture considers the forest as ecosystem. It aims at regulating all life processes in an ecologically stable forest and organizing its establishment and regeneration in a way that all needs related to forests are fulfilled best possible and sustainably, i.e. in a permanent and rational manner." Silviculture, therefore also has the objective of balancing both culture and nature.

A silvicultural system is a sequence of silvicultural treatments performed to obtain a desired outcome for an entire cutting cycle or rotation. Silvicultural treatments should be based on the knowledge about the forest species. (Melgarejo, et al., 2005) If foresters do not understand the requirements for regeneration of timber species or the conditions under which they reach their optimal growth, the success of their silvicultural systems for these species cannot be guaranteed. The more forestry professionals gain a better understanding of forest ecology, the greater is the efficiency and the profitability of forest production and the lower is the damage from forest management operations (Fredericksen, et al., 2001).

Additionally, it is necessary to consider the phenology of trees for silvicultural decision-making. The knowledge about the phenology is required when determining the most appropriate time for harvesting and when establishing the amount and location of seed trees which are excluded from harvesting (Fredericksen, et al., 2001). In the case of species with regeneration difficulties, such as mahogany, it would be advisable to harvest these species after fructification (Quevedo, 1986).

Logging itself can be considered a silvicultural treatment because it reduces the basal area and provides light in the understory. For logging to be considered an actual treatment it should be accompanied by other treatments such as careful planning of extraction, marking of future crop trees and directional felling (Pinto, et al., 2011). It is usually necessary to apply additional silvicultural treatments apart from harvesting to increase the availability of light or create suitable microsites for regeneration of several valuable species. Quevedo (2006), points out that planned harvesting accompanied with silvicultural treatments can promote natural regeneration recruitment for most species. This does not necessarily mean that the regeneration will develop into harvestable trees.

Therefore, it is likely that post harvesting treatments are required to ensure that a certain number of seedlings and saplings become large trees. Otherwise, the sustainable use of the forest could be at risk. (Pinto, et al., 2011)

Silvicultural treatments are generally performed to improve yields of commercially valuable tree species by increasing their recruitment and growth rates (Peña-Claros, et al., 2008). Several silvicultural interventions which have been implemented in sustainable forest management schemes are focusing mainly on maintaining forest structure and protecting ecological functions (e.g., soil productivity and nutrient retention) through controls on harvesting practices. Most "best practice" examples of in tropical forest management to date have relied almost exclusively on reduced-impact logging (RIL).It is an operational system designed to minimize damage to the residual stand. Post-harvest silviculture, on the other hand, is not applied at a commercial scale (Schulze, 2008). Especially interventions which focus on securing the regeneration needed for future harvests are rare (Peña-Claros, et al., 2008). Nonetheless, ensuring sufficient regeneration of commercially valuable tree species is a recent topic in the sustainable management of tropical lowland forest (Mostacedo, et al., 1990). Günther (2011) calls for investigation in methods to apply species-specific assisted regeneration to improve forest stands' quality and long-term productivity.

> *Actually, the application of species-specific regeneration methods would be necessary to guarantee real sustainability for most of the highly valued tree species; however, the enrichment and subsequent management of logged-over stands with natural, highly valued species is, due to short-term perspectives and costs, not an option for the majority of forest concessionaires since forest law does not obligate them to do so. In contrast, the concessionaires rely on natural regeneration and the concept of seed trees. The result obtained from this laissez faire management is that the focus is even more on selective logging with all its collateral effects of high fix costs and extreme impacts on the residual stand.* (Günther, et al., 2011, page 58)

2.3 Forest Management in Bolivia

It is estimated that about half of Bolivia is covered by natural forests. Of this total an area of 41 million hectares is classified as permanent production forests. Within this area there is a potential of at least 28 million hectares for sustainable forest management activity, considered compatible with environmental conservation processes (Quevedo, et al., n.d.).

In recent years, the Bolivian forestry law has democratized the access to forests and enabled significant progress towards sustainable management. With the implementation of the Forest Law 1700, adopted in July 1996, a variety of users gained access to forest user rights. Under Bolivia's former forest law the use of forest for commercial purpose was virtually monopolized by large logging firms. Today, in addition to timber companies, indigenous people, local communities, and landowners have the right to access productive forests. In Bolivia, almost all natural forest belongs to the government; in accordance with the forestry law the government grants commercial harvesting rights to different user groups (see table 1). All groups are required to have a forest management plan that is approved by the forest and land authority (Autoridad de Fiscalización y Control Social de Bosque y Tierra, ABT)[1]. Logging companies which have contracts with the government for 40 years and have to get renewed every five years after a technical audit. If the operation is certified for SFM (such as FSC), it does not need to pass a government audit and contract renewal occurs

[1] In 2009 the ABT replaced the former Superintendencia Forestal (SF) institution created by Forestry Law 1700.

automatically. With at least 28 million hectares available for sustainable forest management, Bolivia to date has 8.5 million hectares under management plans. (Quevedo, et al., n.d.)

TABLE 1: NUMBER AND AREA OF EXISTING FOREST RIGHTS UNTIL 2010 (> 200 HA)

Type of person	Nr. of PGMF	Area (ha)
Forest concessions on public lands to companies	51	3880744
Indigenous community (TCO) or indigenous people	83	1420162
Private property	261	1441809
Farming community	108	804278
Local Social Groups (Agrupaciones Sociales del Lugar, ASL)	20	473155
Forest harvesting contract on public lands	2	225400
Forest concessions on public lands for research	3	262367
TOTAL	528	8507915

Data source: (Quevedo, et al., n.d.)

To authorize legal logging, the ABT must approve the General Forest Management Plans (PGMF) where the strategy and forest management activities are presented. The PGMF has to deal with cutting cycles, minimum cutting diameters (MCD), logging compartments (Area Anual de Aprovechamiento, AAA), seed trees, harvestable volume, silvicultural plan, monitoring and improving practices based on the results of monitoring, management of conservation areas, protection of wildlife and rare or endangered species and other typical activities of a management plan (Quevedo, et al., n.d.)

In Bolivia, the annual allowable cut is not based on a fixed volume per hectare but on the amount of harvestable trees found in a given annual logging compartment (AAA). Harvestable trees are inventoried, measured and marked for harvest in each annual logging compartment, following the rule that 20 percent of the harvestable trees of every commercial species are left as seed trees. Forest managers use this inventory to prepare an annual operational plan (Plan Operativo Anual Forestal, POAF) that indicates the estimated harvestable volume to be harvested in the following year. The inventory is also used for other aspects related to forest management, such as elaboration of (logging) maps. The operational plan is revised and approved by the ABT that grants, regulates, and controls harvesting rights (Peña-Claros, et al., 2011).

The Bolivian Forestry Law and its technical regulations require the application of several management practices. These management practices need to be followed in all areas under forest management larger than 200 hectares regardless of ownership. The management practices required are:

- A general forest management plan (PGMF);
- A forest inventory to develop the PGMF;
- Designation of protected areas within the forest management area;
- Identification and protection of keystone tree species and important areas for wildlife, such as roosting areas, salt licks, and caves;
- Division of the forest management area into logging compartments and annual harvesting areas, requiring the use of a minimum cutting cycle of 20 years;

- Protection of species with low abundances (less than 0.25 trees with a diameter of > 20 cm per hectares);
- A census of commercially harvestable species. The census is the basis for preparing the annual operational forestry plan, which is required to obtain permits for transporting timber. The operational plan includes field maps used to locate harvestable trees, seed trees, land characteristics (slopes, water bodies), and roads to be opened;
- The use of MCD for commercial species. The MDC is defined in the regulations and is specific for species and ecoregions (in the study area MCD is 50cm for all species);
- Retention of 20 percent of merchantable trees as seed trees;
- Annual reports of harvesting activities;
- Establishment of permanent plots to monitor and evaluate the impact of timber harvesting in the forest;
- Plans for wood provision, procurement and processing (only applicable when the forest manager owns a sawmill).
  (Peña-Claros, et al., 2011)

The above management practices, especially the census, the cutting cycle and the determination of the AAA were important advances in the initial phase of the Bolivian forestry model. Unfortunately, no increase of the quality of management has been observed. To date, missing in this process are the silvicultural treatments and effective monitoring. As a result, despite the recent advances in Bolivia, no silvicultural system exists that had been developed for a forest management operation. (Quevedo, et al., n.d.)

The current forest legislation in Bolivia sees the need to implement silvicultural treatments only to a very low extend (Quevedo, et al., n.d.). Articles 1 and 2 of the Forest Act 1700 determined that forest management must be sustainable and Article 9 establishes the precautionary principle in forest management. Article 69 paragraph II b of the Regulation of the Forestry Law (DS 24453) and the Technical Standards refer to the monitoring of the forests to assess their status, growth, performance and implementation of silvicultural treatments. (CINMA, 2012)

Forestry in Bolivia has often been restricted to use, only governed by MCD and pre-harvesting liana-cutting. Few legal forest users in the country are applying silvicultural treatments and monitoring of the forest growth. Permanent sample plots (PSPs) have not been implemented satisfactorily by most companies, resulting that knowledge of how the forest response to harvesting practices is still uncertain. However according to Pinto, et al. (2011) the following silvicultural treatments are being applied in Bolivia:

- Pre-harvest liana-cutting
- Marking of future crop trees
- Liana cutting of future crop trees
- Reduced impact logging (directional felling and controlled log extraction).
- Enrichment planting
- Soil scarification in landings

Liana cutting: The cutting of lianas is possibly the cheapest and the most applied treatment in Bolivia. Because it is usually done during the census, costs are relatively low (Pinto, et al., 2011). The purpose of this treatment is to reduce impact on the remaining forest stand.

Marking of future crop trees: This treatment is gradually being adopted by forest operators in Bolivia and providing positive results. The general objective of the demarcation of FCTs is to prevent or reduce damage during extraction on individuals with commercial value (Pinto, et al., 2011). The collected data allows the analysis about volume, abundance and quality of trees for future harvesting activities. During all logging activities damage to these trees has to be avoided. In some cases FCT are later additionally the target of liberation measurements.

Liberation: Liberation separates young trees from the competition of other tree species with lower commercial value (Hutchinson, 1995). This treatment is aiming to remove shading vegetation that prevents regeneration or future crop trees. Liberation is also performed when a dense tree cover creates competition for space and nutrients (Louman, et al., 2001). Liberation can be done if the desirable plants are located under a closed canopy or in clearings. For the emergence of desirable seedlings in clearings after harvesting, liberation is essential to reduce death, improve quality and accelerate the regrowth of commercial species and thus ensure future extractions and forest sustainability (Pariona, et al., 2000). In some cases, regeneration is overpowered by the competing vegetation which may stop the growth or even kill the seedlings if liberation treatments are not being applied. Pariona et al. (2002) suggest applying liberation treatments at the beginning rather than the end of the rainy season to increase the response to treatments by releasing saplings at the beginning of optimal growth conditions. The authors also emphasize the advantage of manual liberation treatments compared to those using herbicides. Forest areas managed through manual treatments performed well and were found to be less costly.

Despite the urgency to include liberation methods in forest management systems, until today forest operators in Bolivia are only practicing these methods on a trial basis.

Soil treatments: Soil treatments are not very common in the management of tropical forests. There are two exceptions: soil disturbance and controlled burnings. Soil disturbance is the cheapest way to remove the substrate by the use of skidder to expose the mineral soil during forest harvesting. It mostly takes place in clearings where a tree has recently been removed. A study conducted in a Bolivian tropical forest shows that commercial tree regeneration density tends to be greater in scarified areas than in unscarified areas within logging gaps (Fredericksen, et al., 2002). Controlled burning has the purpose to expose mineral soil for seed germination. However, controlled burning is very difficult to perform in log landings in a closed forest and negative consequences of mismanagement can be severe.

Enrichment with seedlings and direct sowing: Studies of natural regeneration in Bolivia indicate that without silvicultural intervention, succession in logging gaps may not result in establishment and recruitment rates adequate for sustained timber production for many tree species. (Schulze, 2008). A commonly proposed solution to solve this problem is to plant seeds or seedlings in lines or blocks in the forest. Enrichment planting is commonly used for enhancing the density of desired tree species in secondary forests as well as in primary forest (Peña-Claros, 2001). With enrichment plantations the composition of regeneration is influenced by planting valuable species produced in nurseries or collected from other sites in the forest. This treatment has been used in several countries aiming for a sustainable production through the principle of planting trees to replace those that have been cut. However, one of the problems in the past was that the loggers planted saplings in the forest only to comply with national quotas but had no system in place to ensure their later survival (Louman, et al., 2001). According to Fredericksen, et al. (2000) most of the plantations have failed due to lack of weed control after planting, assuming that the plated seedlings would survive without further support. Weed control is required for several years ensure the survival of most of the planted trees. Schulze (2008) suggests annual tending during the first threeyears. After this point, planted juveniles may be able to maintain dominant positions without tending, or regular, but less frequent, tending may be necessary to maintain high growth rates (e.g. every 5–10 years). Enrichment planting is often thought to be costly. Nevertheless, in comparison with traditional line-planting, gap enrichment planting it appears to be relatively inexpensive. (Schulze, 2008)

Forest Certification

Bolivia has come into the spotlight of international forest management due to its rapid growth of forest certification, arriving at 2.2 million hectares of certified forest in 2007; which at this time put Bolivia as the leading country worldwide for the certification of natural tropical forests. Ninety seven percent of the certified forest surface corresponded to concessions, reflecting the technical and financial capacity to pass the process of forest certification (Quevedo, et al., n.d.), (Quevedo, 2004). Market advantages motivated the private sector to penetrate decisively and quickly in the forest certification process. However, to date, due to multiple factors, including the lack of legal security and new policies that have discouraged private forestry, the certified area has declined steadily, with 900,000 ha in June 2013. (Quevedo, et al., n.d.)

Forest certification is a voluntary and independent process of verification by qualified specialists. The authorized management plan is put into relation with ecological sustainability, economic viability and social benefits. Bolivia has followed the system of the Forest Stewardship Council (FSC), which has international principles and criteria in addition to national standards. In the social field, the certification generates employment opportunities and training, enforcement of security norms and provision of adequate safety equipment, respect for workers' rights, better salary levels and fair wages, health insurance for workers and their family, among others. For the company or the community, the certification allows them to be recognized as responsible producers. From an environmental point of view, forest certification leads to the preservation of forestry potential and biodiversity. It maintains ecological functions of the forest, protects the flora, the fauna and their habitat as well as water and soil resources. Certified companies can establish long-term businesses and often obtain better prices. It promotes their access to new markets, and enables the incorporation of new species and products to markets. Forest certification in Bolivia has allowed certified operations to benefit from international markets and raise its institutional profile. At the field level, these operations show a good quality of forest management (FSC-called "good management") that is environmentally appropriate, socially beneficial and economically viable. (Quevedo, et al., n.d.)

What makes certification attractive is that it effectively incorporates sustainability elements some of which are not considered by the national laws, regulations. These elements include the identification and management of forests of high conservation value, the application of silvicultural treatments, low-impact logging, the monitoring of responses to forest harvesting (natural regeneration, damage to vegetation, wildlife, among others), strict ban on hunting, conservation of valuable habitats, protection of wetlands, rivers and streams, improving conditions for workers (safety equipment, food, accommodation, salary, health care, and others), good cooperation with neighbouring communities and economic viability of the management plan. (Quevedo, et al., n.d.)

Forest certification has been proven to be an effective tool to improve forest management and increase social living standards. While there are positive developments in forest management quality improvements still need to be made with the application of silvicultural treatments and monitoring of regeneration and forest development. Current management systems are missing the implementation of post-harvest treatments. (Quevedo, et al., n.d.)

3 OBJECTIVE

The study was conducted in order to get to a better understanding of the regeneration of three important timber species in the forest management unit of CINMA. The study is analysing different states of forest regeneration and is dealing with natural regeneration as well as artificial regeneration (enrichment plantings). The objective of this study was to find solutions of how CINMA can guarantee sufficient regeneration of the three commercially important timber species Cuta (*Apuleia leiocarpa*), Roble (*Amburana cearensis*) and Paquió (*Hymenaea courbaril*) in its FMU. The following research questions were addressed in order to achieve the above mentioned objective:

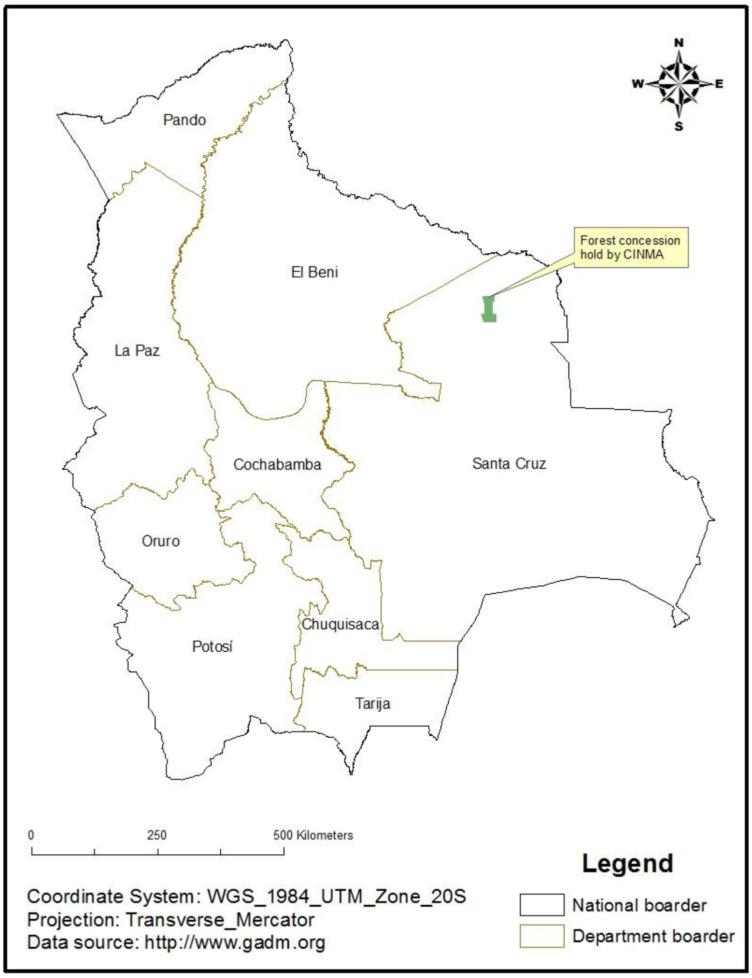
1. Are the three tree species Cuta, Roble and Paquió sufficiently represented by Future Crop Trees (FCT) to secure a sustainable use in the near future?
2. How successful is the enrichment planting on landings, skid-trails, in undisturbed forest and in forest which has suffered from forest fires?
3. Is the regeneration of commercial timber species, in particular of Cuta, Roble and Paquió, in logging gaps and skid-trails sufficient to justify liberation of natural regeneration as a silvicultural treatment?

4 METHODOLOGY

4.1 STUDY SITE

The study was realized in the FMU hold by the timber company SINMA ltda. The FMU comprises two concessions which are managed as one unit. The forest is situated in the north-astern part of the department Santa Cruz in lowlands of Bolivia (see figure 1). On site logs are sawmilled and transported to clients throughout Bolivia but mainly to its processing plant in La Paz (Dekma Bolivia S.A.). The saw-mill is a closed site and is located next to the FMU.

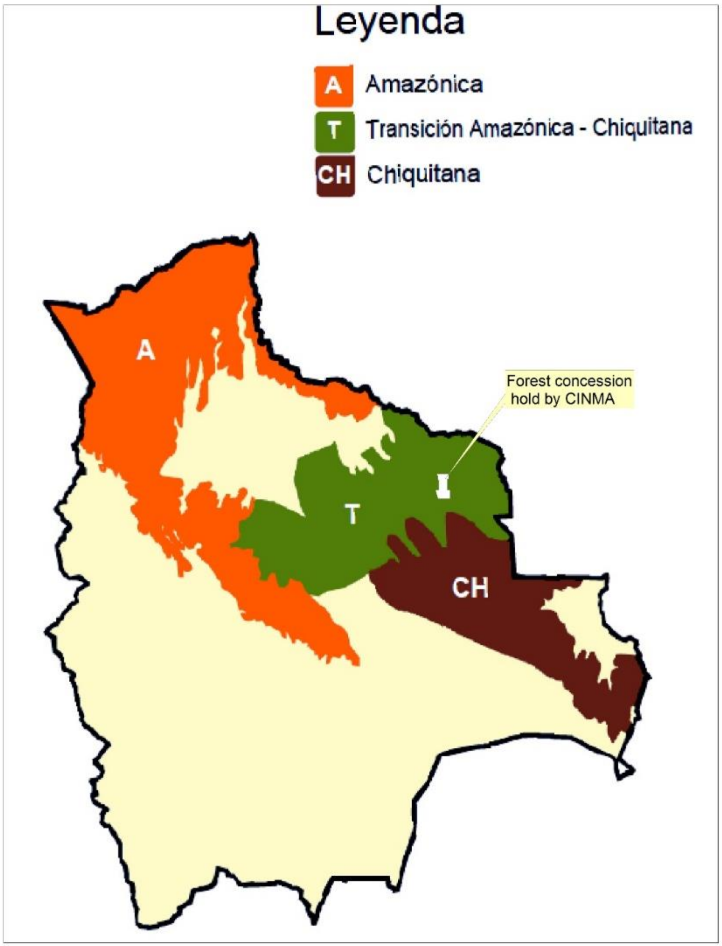
FIGURE 1: LOCATION OF THE FOREST CONCESSION IN BOLIVIA (DATA SOURCE: (GADM)



The total area of the FMU is 119200 ha. The company has set aside 8696 ha (7.3%) for conservation and 3340 (2.80%) as protected area, leaving 107162ha (89.90%) for timber production. (Cinma, 2014)

The tropical forests of the region of Bajo Paraguá were the FMU is situated is the transition zone between the Chiquitano dry forest and the Amazon forest (see figure 2) (Villegas, et al., 2008). This region is dominated by a continuous forest which includes a combination of species from the Amazon region and the Chiquitano region. The forests of Bajo Paraguá have a higher diversity than the Chiquitano dry forests but a lower diversity than the Amazon forest. The vegetation in the study site can be classified as a seasonally dry humid tropical forest. The forest in the humid Amazon region north of the study site is characterized by high forest, whereas the Chiquitano forest in the south is dominated by smaller trees and grasses. There are species in the transitional zone which are unique to this region. The emergent trees in this region reach a height of 25 to 30 meters. The forests of Bajo Paraguá are similar in structure to the Amazon forests, but have a lower basal area and density of palms, and increased liana infestation (Villegas, et al., 2008). In this forest the most common families of tree species are Leguminosae, Palmae, Euphorbiaceae, Moracera, Anacardiaceae, Fabaceae, Lauraceae and Apocynaceae. The most common tree species include Verdolago (*Terminalia amazonica),* Serebo *(Schizolobium amazonicum),* Amargo *(Simarouba amara)*, Mururé, (*Batocarpus amazonicus)*, Cambara (*Erisma uncinatum)*, Cambara Macho (*Qualea paraensis*), Cuta (*Apuleia leiocarpa),* Roble (*Amburana cearensis*), Paquió (*Himenaea coubaril*) and Jichituriqui (*Aspidosperma spp*.). Mahogany (*Swietenia macrophylla*) and Cedro (*Cedrela fissilis*) have been abundant in the forest but have been reduced significantly by overexploitation. Also present in the forest is a variety of palm trees such as Motacú *(Attalea phalerata)*, Marayau *(Bactris major*) and Asaí *(Euterpe precatoria*).

FIGURE 2: MAP OF THE MAIN ECOLOGICAL REGIONS WITH POTENTIAL FOR FORESTRY IN BOLIVIA. (BASE MAP COPIED FROM (VARGAS, ET AL., 2005)



The forests of the transitional zone show different topographies and inclinations but in most cases they are situated on top of riverside terraces. The altitude varies between 300 and 800 meters above sea level. The relatively plane landscape include a number of outcrops of small hills and isolated Inselbergs. Two Inselbergs are situated in FMU, rising above an undulating plain with an average elevation of about 240 meters. The soils are shallow, nutrient-poor, well-drained and include many soil associations (Vargas, et al., 2005), (Cinma, 2014).

The climate in the FMU varies from tropical sub-humid in the south to tropical hum in the north. The mean annual temperature is 25-26°C with the highest temperatures in October and November and the coldest period in July. The mean annual rainfalls vary around 1500mm. The dry season falls into the winter months from June to September. The highest precipitation occurs between October and March. The relative humidity varies between 82-75% in the months of December to March and between 70-55% in the months of July to September (Villegas, et al., 2008).

The FMU has been subjected to selective logging from about 1970 until 1997 through a long-term contract from the old forest regulations. Species that were exploited were: Mahogany (*Swietenia macrophylla*) and Cedro (*Cedrela fissilis*). In recent years before the adoption of the new forestry law (1993-1996) the use of Roble (*Amburana cearensis*) started. Since 1998 the CINMA carries out the exploitation, planned and organized under a written management plan which meets the New Forest Regime and the Standards (Principles & Criteria) of the FSC FMC and comprises the use of additional species (see chapter 4.2)

Inside the FMU there are some areas were forest fires repeatedly caused immense damage to the forest cover during the last years.

4.2 FOREST MANAGEMENT PRACTICE IN THE STUDY AREA

The company CINMA is managing its FMU in a polycyclic system which is based on selective logging. The system includes a cutting cycle of 25 years (legal standard is 20 years) and minimum cutting diameters (MCD) of 50cm. At present, the following species are being harvested: Roble (*Amburana cearensis*), Cambara (*Erisma unsinatum*), Paquió (*Himenaea coubaril*), Cuta (*Apulaia leiocarpa*), Cambara Macho/Angelyn (*Qualea paraensis*), Verdolago (*Terminalia spp*.), Jichituriqui (*Aspidosperma spp*.), Tajibo (*Tabebuia sp*.) and Yesquero Negro (*Cariniana estrellensis*). Five of these species account for 98 percent of the harvest (see table 2).

TABLE 2: HARVESTING RESULTS OF 2013 (COPIED FROM (CINMA, 2014)

Species	Amount of logs	Volume (m^3)	Volume per hectare (m^3/ha)	Volume proportionally on TOTAL
Cambara	3621	9368	2,4	37%
Cuta	4983	8409	2,15	33%
Paquió	911	2613	0,67	10%
Cambara Macho	1533	2434	0,62	10%
Roble	1490	1990	0,51	8%
Verdolago	160	343	0,09	1%
Tajibo	88	111	0,03	0,5%
Jichituriqui	60	78	0,02	0,3%
Yesquero Negro	3	5	0,001	0,02%
TOTAL	**12849**	**25351**	**6,49**	

The yearly harvesting activities are taking place in restricted annual cutting compartments (AAA). The annual harvesting is done in up to three AAA. Before any logging activities can take place the company has to complete a full census of harvestable trees in the AAA and present its harvesting plan in an annual operating plan (Plan operative annual forestall; POAF) to the Forest and Land Authority (Autoridad de Bosque y Tierra ; ABT). A registration and mapping of 100% of harvestable trees is done clearly identifying each tree (species, DAP, commercial high, quality and location) referenced by coordinates in the AAA. During this activity a plaque with an individual number is placed at each harvestable tree. Twenty percent of the harvestable trees which are registered during the census are left as seed trees. Before the felling activities start, lianas which grow on the selected trees are being cut. Once the preparations are finished, cutting is done by directional felling, reducing the impact on the remaining vegetation. Extraction of the timber is done by skidder using previously planned skid-trails to reduce the impact on the remaining forest. Logs are gathered on landings where they are being parted, measured and later loaded on trucks to be brought to the sawmill.

Since 1998, the company is certified by FSC for its forest management and its chain of custody. The forest certification process has brought some minor changes to the management of the FMU. Beside many other modernization measurements the company has agreed on the integration of additional silvicultural treatments in their management of the forest. In 2012, the company has produced a manual covering the different silvicultural treatments which are being implemented, including those that are so far run on a trial basis. The treatments are:

1. Selection and protection of seed trees
2. Demarcation of future crop trees (FCTs)
3. Liberation of the FCTs from lianas
4. Scarification of landings
5. Enrichment planting on landings, skid-trails, in undisturbed forest, in forest which has suffered from forest fires and on abandoned logging camps.

Of the above listed treatments, only the protection of seed trees is an integral part of the forest management by CINMA. Twenty percent of the trees which have been identified during the census are excluded from the harvest and left in the forest as seed trees.

4.3 STUDIED SPECIES

4.3.1 Cuta (*Apuleia leiocarpa* (J. Vogel) J.F. Macbride)

Family: Caesalpiniaceae (Leguminosae)

Description*:* *Apuleia leiocarpa* is an emergent tree up to 45 m high, and diameters reaching more than 100 cm. The species is characterized by an irregular open crown, an irregular straight cylindrical trunk in dense forest and a little twisted in more or less open places. Its base is wavy with basal buttresses. The outer bark is greyish orange and peals of in irregular and large laminar plates. The inner bark is fibrous, with interspersed bands between pink and cream. The leaves are alternate, compound and imparipinnade with alternate and elliptical leaflets. The flowers are small, white and are arranged in axillary racemes. The fruit is an indehiscent legume of coffee colour, pubescent, asymmetric and flattened containing two compressed seeds (Justiniano, et al., 2003), (Salazar, et al., 2001). The wood of *A. leiocarpa* is yellow, with differences between sapwood and heartwood, the latter being more intense coloured.

(For species illustration see ANNEX 2)

Distribution: *Apuleia leiocarpa* is a species of the humid to sub-humid Amazonian forests. It has a high distribution in Brazil, Bolivia, Peru, Paraguay and Argentina; with few reports in Venezuela and Colombia. In Bolivia the species is restricted to the Amazon region of the country. It can be found in the departments Pando, the north of La Paz, Beni and northeast of Santa Cruz. In Pando and the forests of Bajo Paraguá in Santa Cruz, an average density of 2.5 trees per hectare has been observed. Lower densities have been found in Amazonian forests of northern La Paz (Villegas, 2009) (Justiniano, et al., 2003), (Salazar, et al., 2001).

Ecology: The species shed its leaves during the dry season. *Apuleia leiocarpa* is a partially light demanding species. It is flowering from September to October; ripe fruits are dispersed by wind during December and January. (Justiniano, et al., 2003) Climatic types, based on the classification of Koppen, where *A. leiocarpa* is located are: tropical, humid subtropical, humid temperate and subtropical, with average temperatures ranging between 17 and 27 º C, minimum temperatures between 12 and 26 º C. and maximum temperatures between 21 and 28 º C. This species is moderately tolerant to low temperatures (Villegas, 2009), (Salazar, et al., 2001). The soils to which *A. leiocarpa* is associated are moderately well drained to well drained, between moderately deep and deep, mostly poor of nutrients, lateritic and acidic, with a loamy clay and basaltic substrate. It is found in undulating topography, usually in high places (Villegas, 2009).

Apuleia leiocarpa can live in a wide range of forest successional stages, as has been described by several authors (Silva, et al., 2003). The species is a good competitor which explains its presence at all stages of forest recovery. It behaves as a shade tolerant species in the first stage of his life. *Apuleia leiocarpa* seedlings require shade. Once established, the trees grow vertically to the canopy in search of light. (Villegas, 2009). *Apuleia leiocarpa* has a diameter distribution corresponding to an inverted "J". Its abundance in the study area (DBH > 20 cm) is 1.15 trees / ha (Villegas, et al., 2008).

Apuleia leiocarpa is susceptible to drought and heat stress. The species cannot be re-established in completely deforested areas. Canopy openness has positive impacts on adult individuals as it improves their growth but is not conducive to regeneration. It has been reported that the species is growing well on burned areas. It has been found that in an Amazon forest area three years after burning one of the most abundant tree species regeneration was *A. leiocarpa* (Villegas, 2009). The species is also found in cultivated areas, pastures, abandoned pastures and clearings where it is usually found in clusters of trees of all ages.

Wood: The wood of this species is of considerably high density. The dry wood has moderate resistance to decay and termite resistance is low. (Villegas, 2009), (Salazar, et al., 2001)

Growth: Diameter growth of *A. leiocarpa* is moderate. Having measured 221 individuals in two forest types, Villegas (Villegas, 2009) finds an average growth of 3.4 (± 0.3) mm/yr. The largest diameter growth registered for this species occurred in trees from 40 to 80 cm DBH averaging in 4mm/yr.

Regeneration: Although this species has potential for sustainable use, it is necessary to pay attention to its regeneration. The species shows abundant regeneration even in disturbed forests and rocky areas (Villegas, 2009). Nevertheless, the regeneration status for this species has been classified as problematic by Mostacedo, et al. (1990). Little regeneration exists on sites were it is harvested. The potential mechanisms for regeneration problems of this species are not well understood (Mostacedo, et al., 1990). Villegas (2009) sates that for *A. leiocarpa* it might be necessary to implement enrichment treatments at an early stage, taking into consideration that it is shade tolerant but requires sufficient light in an adult stage.

4.3.2 Roble (*Amburana cearensis* (Allemão) A. C. Smith)

Family: Fabaceae (Leguminosae)

Information about this species is scanty and scattered, particularly in respect to its biology and ecology. (Leite, 2005)

Dendrological characteristics: *Amburana cearensis* is a large tree which grows up to 40 m high and reaches a diameter up to 150 cm. The species is characterized by a round crown, thin and grey-green foliage and slightly branched upward branches. The bole is cylindrical-conical, straight and clean. The outer bark is smooth, reddish brown, with papery peels. The yellowish inner bark is of granular texture and has a strong odour, exuding viscous and yellowish gum. Leaves are alternate, compound and imparipinnate. The whitish-yellow flowers are arranged in axillary racemes. The fruit is a woody vegetable, elongated, with 1 to 3 aspect seeds. Leaves of the seedling are similar to those of the adult trees: compound, leaflets alternate, oblong, entire edge, rounded base and whitish below. They have a characteristic odour when they are squeezed (Justiniano, et al., 2003).

(For species illustration see ANNEX 3)

The wood of *A. cearensis* is used for furniture and decorative veneers. Heartwood is yellowish amber, turning to brownish orange after long exposure (woodfinder, n.d.).

Distribution: *Amburana cearensis* is found in Bolivia, Brazil, Northern Argentina, Paraguay and Peru (Leite, 2005). In Bolivia, the species is widely distributed in the departments Pando, Beni, La Paz and Santa Cruz (Justiniano, et al., 2003).

Ecology: *Amburana cearensis* has a restricted ecological distribution (Leite, 2005). *A. cearensis* is an emerging species, deciduous, partly light demanding, common in the semi deciduous hardwood forest, the Amazon forest and transition zones. The species generally grows at shallow, well-drained soils near rocky outcrops. The terrain where the species occurs is in the majority of cases constituted by plateaux ranging from altitudes of 500–1000 m. Concentration of the species is associated with deep richer soils (luvisols) in places of moderately hilly topography. The species is generally associated with regions of low rainfall. (Leite, 2005). Once the trees are established they are very resistant to drought (Facultad de Ciencias Agrarias, Universidad Nacional de Asunción). The species is intolerant to shade (Mostacedo, et al., 1990).

Flowers appear from March to May and fruits ripen between July and September. The seeds are dispersed by wind (Justiniano, et al., 2003), (Vargas, et al., 2005). However, it is important to note that this species bears fruit only every two to three years (Villegas, et al., 2008).

Amburana cearensis is characterized by a low population density (Leite, 2005). Nonetheless, it is a species which has been extensively exploited due to its high commercial value. In some places the species has disappeared due to overexploitation (Ymber Flores Bendezú, 2014). The IUCN Red List of Threatened Species cites *A. cearensis* as being endangered (Leite, 2005). In the study area the species is present with a density of 0.1 trees/ha (DBH >20cm) (Villegas, et al., 2008). The diameter distribution of *A. cearensis* corresponds to an inverted "J".

Growth: A study conducted in a Chiquitano forest showed an average annual increment of 0.5 cm for *A. cearensis* (López, et al., 2012). Another study recorded increments of 0.51 cm/ year in plantations and 0.38-0.41 cm/ year in enrichment plantations (Ymber Flores Bendezú, 2014). The monitoring results of forest increments in the forests of Bajo Paraquá show an annual increment of 0.4cm for Roble under normal conditions (without silvicultural treatments) (Villegas, et al., 2008).

Regeneration: The regeneration status of *A. cearensis* has been describes as poor by Mostacedo, et al., (1990) and solutions for improvement are unknown. Very little natural regeneration of the species occurs on sites where it is found naturally as adult trees (Mostacedo, et al., 1990), (Fredericksen, et al., 2000). In addition, little silvicultural knowledge exists about how to establish regeneration. Mostacedo, et al. (1990) see iregular seed production, poor seed germination and the lack of large clearings with adequate light availability as causes for the extremely poor natural regeneration. Leite (2005) reports the need of shade conditions for the early development of *A. cearensis*. Fredericksen et al. (2000) in their conclusion of a study on the invasion of non-commercial tree species after selection logging in Bolivian tropical forests even warn that in Bolivian dry forests a similar commercial elimination which had happened to mahogany (*Swietenia macrophylla*) might as well occur for *A. cearensis*. The species' low densities, high extraction rates, and poor regeneration make it very vulnerable for extinction.

4.3.3 Paquió (*Hymenaea courbaril* L.)

Family: Caesalpiniaceae (Leguminosae)

Dendrological characteristics: *Hymenaea courbaril* is a big tree, up to 40 m tall and a diameter up to 110 cm. The bole is clean, cylindrical, very straight and without buttresses. The crown is round to ovoid and the foliage bright green. The external bark is smooth with an ashy colour. The internal bark is reddish, exuding a gummy secretion that crystallizes. Leaves are alternate, bifoliolate with translucent dots on the lamina. The leaves of the seedlings are similar to the ones of the adult trees but are relatively larger. The white flowers appear in the terminal panicles. The fruits are ovoid legumes, woody indehiscent, of coffee colour and contain seeds, covered by a floury aryl. The sweet white pulp surrounding the seeds is edible. (CANABIO), (Justiniano, et al., 2003)

(For species illustration see ANNEX 4)

The wood, rich in colours and durable, has a variety of uses. It is moderately difficult to work with but beautiful when polished. The wood is comparable with mahogany and is used in carpentry and flooring. (CANABIO)

Distribution: *Hymenaea courbaril* has a wide distribution. In the Caribbean the species grows through the Antillas Mayores and Menores. The continental distribution area extends from central Mexico to south Bolivia and southern central Brazil. In Bolivia, the species is widely distributed in the departments La Paz, Pando, Beni and Santa Cruz; here it is found from 200 up to 600 m.a.s.l. (Justiniano, et al., 2003)

Ecology: *Hymenaea courbaril* is a semi-deciduous species, common in almost all tropical forests from the Amazon to the dry forest (Justiniano, et al., 2003). Best growth of the species occurs where there is a rainfall of 1.900 to 2.150 m / year but it can grow in areas with just 1,200 mm / year. Its average annual temperature ranges from 20 to 30 ° C. (CANABIO) Like most hardwoods species *H. courbaril* grows best in deep, fertile, moist and well drained soils. It can grow in soils of any texture from sands to clays, but grows best in sandy soils. Most genotypes grow on slopes and hilltops but are rarely found in lowland poorly drained alluvial soils. (Francis, 1990)

Hymenaea courbaril flowers from October to January and fruits are ripening from June to September. The fruits are available as an important feed source for wildlife during the dry season.

Hymenaea courbaril is partially shade-tolerant, intolerant of shade when mature. It grows slowly under part shade and can persist under considerably full shade for a number of years, but requires full or nearly full vertical light for complete development. Trees of this species which grow on open sites have a few short stems and large crowns. Young trees growing under part shade develop a longer and straighter shaft. (CANABIO) In the forest of Bajo Paraquá *H. courbaril* is present with a density of 0.22 trees/ha (DBH >20 cm) (Villegas, et al., 2008).

Growth: The species is characterized by a moderate growth rate. It is a species which can get very old and is able to reach large size. Average diameter-growth can be expected to be between 0.45cm/year and 0.53 cm/year. (Francis, 1990), (Villegas, et al., 2008)

Regeneration: The regeneration status of *H. courbaril* has been describes as problematic by Mostacedo, et al. (1990). Poor or irregular seed production and high rates of seed predation are being seen as the causes of regeneration failure. (Mostacedo, et al., 1990) Seedlings and saplings are susceptible to being choked by weeds, bushes and trees of accelerated growth which protrude above them. Once the trees have established themselves as dominant trees, other trees in the stand have little effect on growth. (CANABIO)

4.4 DATA COLLECTION

This report includes three separate field studies. Data for these studies were collected between April and June 2014. The first section evaluates the data collected during the demarcation of FCTs. In the second part the enrichment plantings are evaluated. The third section is showing a regeneration study in old logging gaps.

4.4.1 Section 1: Future Crop Trees

The aim of this section is to compare the abundance of FCT of the three timber species dealt with in this report with the amount of harvested individuals. The data for this study has been obtained from six plots in the annual cutting compartment AAA-2014-1, *Los Calambres*. All data concerning the harvested trees are taken from the control of chain of custody for this annual cutting compartment. This database is created by the company during the census in the year before the harvesting activities take place and updated during all following activities.

Marking of the FCTs has been taken place before the logging activities started. On 4.2 percent (60ha) of the area of the AAA (1417.5ha) FCT were marked. Six plots, each measuring 10 hectares, have been distributed throughout the annual cutting compartment. For an equal representation of the different forest types, the operative map, showing all harvestable trees, was used to distribute the six plots (see ANNEX 5). Plots were distributed so that sites with different harvesting densities and harvested species were represented proportionally. Only commercial species and species with potential for commercialisation in the future were marked. Trees have to show a DBH of at least 20 cm and a quality of 1 or 2, to be marked as FCT. The marking of the FCT followed principally the same methodology normally used during the census. Following a pica (subdivision line, dividing the annual cutting compartment in north-south direction in blocks of 100 m with) trees were marked 25 m to each side. The work was done by two tree spotters, one working to each side of the pica and a third person who was recording information for each tree. The tree spotters were identifying the trees, measuring their DBH, giving them a plaque with an individual number, marking them with spray and cutting the lianas infecting the tree.

4.4.2 Section 2: Evaluation of enrichment plantings

Since 2012, the company CINMA is collecting seeds from the main wood species logged. These seeds are being used in a nursery in order to raise seedlings for enrichment planting. During the harvesting years 2012 and 2013, seedlings have been planted on a trial basis in different locations in the field to enrich the regeneration. Enrichment planting has been conducted on landings, skid-trails, in undisturbed forest and in forest which has suffered from forest fires. In the enrichment planting the tree species Cuta (*Apuleia leiocarpa*), Roble (*Amburana cearensis*), Paquió (*Hymenaea courbaril*) and Mahogany (*Swietenia macrophylla*) have been used. The plantations of Mahogany are not being included in this study.

In table 3 an overview is given on the enrichment planting which has been done by the company CINMA (also see ANNEX 6). Until December 2013, a total of 921 seedlings were planted on skid-trails, landings, in undisturbed forest or in forest which had suffered from forest fires. In landings, four to nine seedlings were planted depending on the size of the opening. On skid-trails six to seven seedlings were planted with a spacing of 20 m. In undisturbed forest and forests which had suffered from forest fires, planting was done in lines, opened with machete and using a spacing of 10-20 m.

During April and May 2014 all of the plantations which are listed in table 3 were visited and measured, except the ones in the AAA 2007-A, where data were not satisfactorily recorded after planting.

TABLE 3: OVERVIEW OF ENRICHMENT PLANTING

Year of implementation	AAA	Location	Units	Nr of seedlings
2012		burned forest	16 lines	153
	2006B	landings	6 landings	44
	2007-A	landings	5 landings	32
	2006-B	skid-trails	4 skid-trails	49
	2007-A	skid-trails	6 skid-trails	38
2013		burned forest	4 lines	81
	2007-2	landings	4 landings	69
	2007-3	landings	7 landings	43
	2013-1	landings	5 landings	6
	2007-2	skid-trails	4 skid-trails	24
	2007-3	skid-trails	7 skid-trails	42
	2013-1	skid-trails	5 skid-trails	46
	2006-A	undisturbed forest	2 lines	29
		undisturbed forest	27 lines	265
TOTAL				921
TOTAL		burned forest	20 lines	234
		undisturbed forest	29 lines	294
		landings	33 landings	194
		skid-trails	26 skid-trails	199

In order to compare the growth and survival rate of the planted tree seedlings an evaluation has been conducted, taking also into account already existing data. For the field study, maps have been designed for a better orientation in the forest. Between May and June 2014 the enriched sites have been visited to gather data on survival and growth of the plantations. Seedlings were first cleared from competing vegetation before the health status of the seedling, its received light and its height was recorded. Seedlings were classified as alive or dead. The illumination was recorded as 1 (full light), 2 (vertical light), 3 (horizontal light) and 4 (without light). The height of the seedlings was measured from the root base to the tip of the longest branch, ending at the leave base.

4.4.3 Section 3: Regeneration in logging gaps and skid-trails

For the regeneration study, logging gaps in areas harvested in 2011, 2012 and 2013 are analysed. The selected logging compartments (AAA) for the study are shown in table 4.

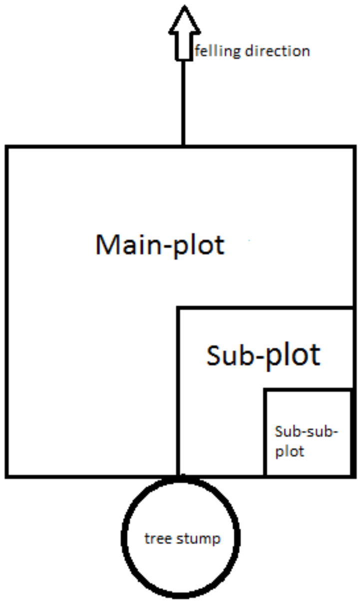
TABLE 4: ANNUAL CUTTING COMPARTMENTS (AAA) USED FOR THE REGENERATION STUDY

year of harvest	Nr. of AAA	Name of AAA
2013:	2007-2	Lechuza Junior
2012	2006-B	Las Lagrimas
2011:	2006-A	Los Holandeses

Field maps were designed, showing the location of harvested trees. Gaps were chosen where trees of one of the three tree species of this study had been cut. In total a number of 63 gaps were analysed, giving a sample of seven gaps per harvesting year for each tree species. Two methods were applied, one to record the composition of the new regeneration and a second to point out leading individuals within the regeneration of the logging gap. For the identification of the leading individual, up to 10 commercial and non-commercial trees which were growing in the gap and occupied the canopy were recorded. Only trees which showed a height of at least three meters and which were not overgrown by competing vegetation were listed.

To study the composition of the regeneration sample-plots, each with a sub-plot and a sub-sub-plot, were set up. In the logging gaps the plots were set up right next to the tree stamp in the direction were the tree had fallen (see figure 3). The main-plots sized 4x4 m, the sub-plots 2x2 m and the sub-sub-plots 1x1 m. For this study it was not necessary to measure the specific height of the regeneration. Therefore, the regeneration in the plots was listed according to their size classes described by Fredericksen, et al. (2000). In the main plot trees taller 150 cm were recorded. In the sub-plot the regeneration >30 and <=150cm was recorded. Seedlings which were smaller than 30 cm were recorded only in the sub-sub-plot (see table 5).

FIGURE 3: LAYOUT OF THE SAMPLINGS PLOTS IN LOGGING GAPS



Apart of the logging gaps, the regeneration was also analysed in plots set up on the skid-trail 50 m away from the tree stamps of the analysed logging gaps in the direction were the trunks had been extracted. The sample-plots at the skid-trails measured 3x5m, the sub-plot 2x2m and the sub-sub-plot 1x1m (see table 5). The regeneration was recorded using the same methodology as in the logging gaps. Due to the much smaller canopy opening compared to the logging gaps, leading individuals were not recorded on the skid-trails.

TABLE 5: PLOT MEASUREMENTS:

Plot	Plot-size (m)		Regeneration type	Size of the regeneration recorded
	Logging gap	Skid-trail		
main	4x4	3X5	sapling	>150cm
sub	2x2	2x2	Large seedling	>30cm - <= 150cm
sub-sub	1x1	1x1	Small seedling	<= 30cm

During the implementation of the study it was realized, that there was a significant dependence of the regeneration to the forest type. Therefore it was additionally recorded in what kind of forest the logging gap and the skid-trail was located. The forest was classified either as a low forest or a high forest and additionally taken into account if it had suffered from forest fires during the last years. In table 6 the amounts of study sites are listed per forest type.

TABLE 6: DISTRIBUTION OF LOGGING GAPS AND SKID-TRAILS STUDIED PER FOREST TYPE AND HARVESTED YEAR

Forest type	**Year of harvest**			**TOTAL**
	2011	**2012**	**2013**	
High forest	2	15	18	**35**
Burned high forest	9			**9**
Low forest	2	6	3	**11**
Burned low forest	8			**8**
TOTAL	21	21	21	**63**

4.5 DATA ANALYSIS

4.5.1 Section 1: Future Crop Trees

Only a number of the trees which are marked as FCT will grow to a harvestable size until the following harvesting intervention in 25 years (cutting cycle). Unfortunately no reliable data on the growth rate of the studied species in the FMU existed when this study was conducted. Therefore, data about the estimated growth-rates to calculate the DBH-increment of the trees until 2039 were gathered through a literature study (see table 7). With this data the increment of the FCT during the 25 years of the cutting cycle was calculated.

TABLE 7: DIAMETER GROWTH OF THE STUDIED SPECIES (SEE ALSO CHAPTER 4.3)

Species	Growth per year (mm/yr.)	Increment in 25 years (cm)
Cuta	4	10
Roble	5	12,5
Paquió	5	12,5

When calculating sustainable harvesting limits, the natural mortality of trees should be considered at all life history stages. To determine the number of surviving trees at the end of the cutting cycle a formula, given by Fredericksen et al. (2001) was used. The mathematical expression is shown in the text box below.

$Ns = Nc * (1-m)^c$

Where:
Ns = Number of surviving trees at the end of the cycle
Nc = Current number of trees
m = Mortality percentage
c = Cutting cycle in years

According to their measured diameters the FSC were first put into diameter classes to allow for presentation in a diagram. The mortality in the diameter classes above 20cm can be considered to be very low. For this study, a mortality percentage of 0.01 (proposed by Fredericksen, et al. (2001)) was taken. Furthermore, it was assumed that all FCT will keep their quality (1 or 2) while maturing and that the damage to trees during logging activities are minimal and the likelihood of unexpected events (fires, floods, etc.) is low.

4.5.2 Section 2: Evaluation of enrichment plantings

For the evaluation of the plantations, data which was gathered by the company during the last years was added to the data collected during the fieldwork in 2014. Planting and measuring of the seedlings were not always done during the same month of the year. Nevertheless, planting was always done during the month October and November and evaluations during April, May or October. To facilitate the comparison of growth and survival of the seedlings, a rough age in half-year sequences was given to the plantation. Therefore, evaluated plantations were either half a year, one year or one-and-a-half years old.

To test for significant in differences in growth and survival rates of the seedlings a two-sample t-test was used with $\alpha = 0.05$.

4.5.3 Section 3: Regeneration in logging gaps an skid-trails

During the fieldwork the species names were recorded as the tree spotter were given them. These names were later compared with a number of different sources (INFOBOL; MACA; OIMT, 2004), (IBIF) to determine their scientific names. In a number of cases the literature showed that the common name was given to more than one species. In this case the species was continued being recorded without a scientific name though it was most important to identify the commercially valuable species, of which names were clearly given.

5 Results

5.1.1 Section 1: Future Crop Trees

On the 60 ha of the study site a total of 21 Roble, 12 Cuta and 2 Paquió were marked as FCTs (see figure 4). The species Roble was almost equally represented in all diameter-classes below the MCD (50 cm). Of each of the species Cuta and Paquió, one individual, bigger than the MCD, was found. It is not clear why they were not being selected for harvesting. As both of them were recorded with quality 2 it is assumed that they will suitable for harvesting in the cutting cycle.

After adding the calculated increment and estimated mortality to the FCTs, six Roble, four Cuta and one Paquió tree are falling in the diameter-classes big enough to be harvested in 2039 (see figure 5).

Figure 4: Actual DBH-class distribution of FCTs by species

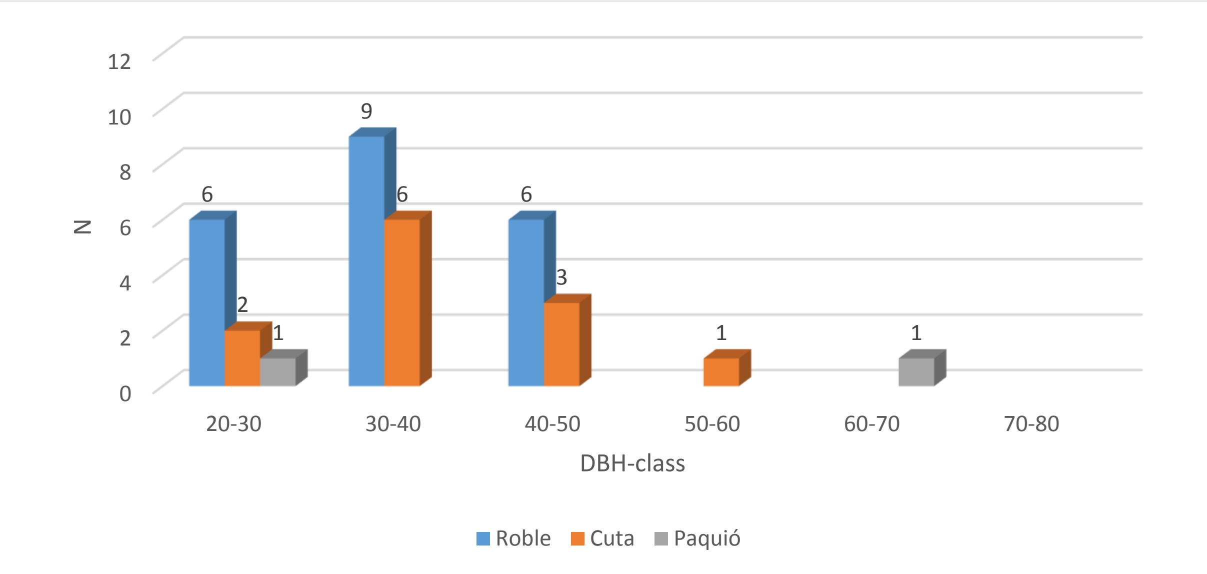
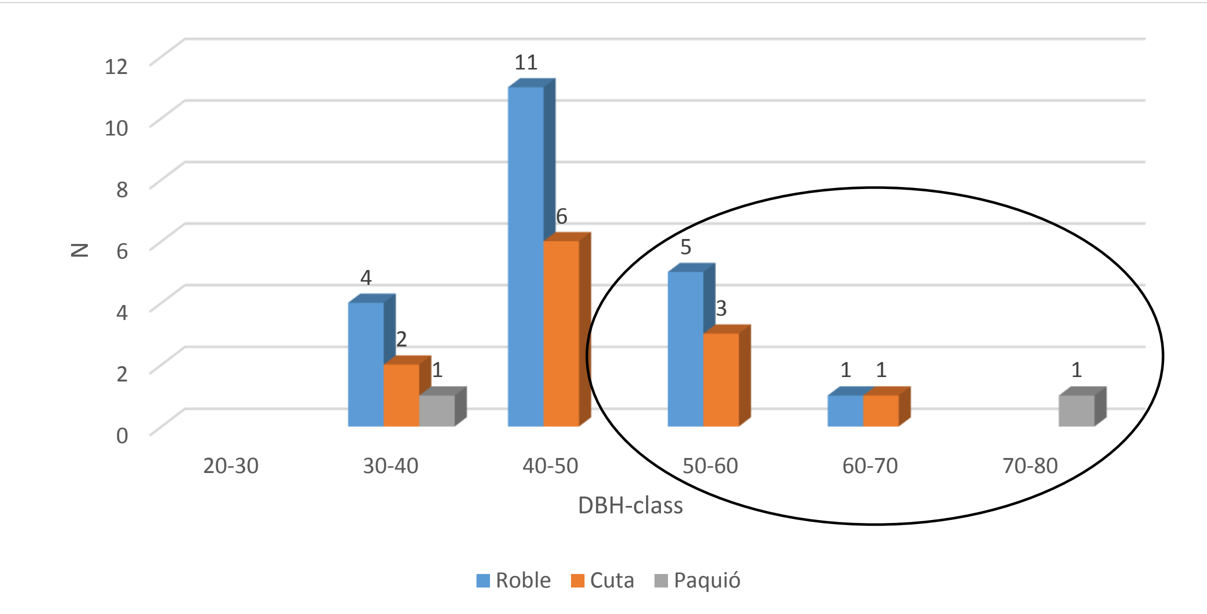


Figure 5: Future (in 25 years) DBH-class distribution of FCTs by species



If the analysed trees which will grow into harvestable size until 2039 are being extrapolated by the total area of the AAA and then compared with the harvested trees of 2014, two species (Paquió and Roble) show a higher representation of harvestable trees for 2039 then harvested trees in 2014 (see table 8) For Cuta the calculated harvestable trees in 2039 were lower than the harvested trees in 2014. There will be less trees of this species available for the next harvest then there were in 2014.

TABLE 8: NUMBER OF TREES PER HECTARE (N/HA):

Species	harvested trees in 2014 (N/ha)	harvestable FCTs in 2039 (N/ha)
Cuta	0.34	0.31
Paquió	0.05	0.08
Roble	0.09	0.47

5.1.2 Section 2: Evaluation of enrichment plantings

The purpose of the evaluation of the enrichment planting was to compare the effectiveness of the plantations on landings, skid-trails, in undisturbed forest and in forest which has suffered from forest fires. To quantify and validate the success of the plantations, survival- and growth rates per species and location are being analysed below.

Survival

The survival rate was relatively good in three of the four locations were seedlings were planted. In the burned forest a significantly lower survival rate during the first six months after planting, was observed when comparing it to the other locations (see table 9). The significance of survival difference between burned forest and the three other locations was tested with a two-sample t-test (see table 10). The survival until the second evaluation was much higher; the remaining seedlings seemed to have established well after the first planting-shock.

TABLE 9: SURVIVAL RATE OF ALL SPECIES

Location	Evaluation 1	Evaluation 2	AVERAGE
Undisturbed forest	89%		89%
Skid-trails	96%		96%
Landings	91%		91%
Burned forest	67%	97%	82%

TABLE 10: VARIANCE TEST FOR SURVIVAL AFTER 6 MONTHS

t-Test: Two-Sample Assuming Unequal Variances		
Location of enrichment planting	***Burned forest***	***3 other locations***
Mean	0,331646	0,077869
Variance	0,222219	0,071953
Observations	395	488
Hypothesized Mean Difference	0	
df	595	
t Stat	9,523904	
P(T<=t) one-tail	2,07E-20	
t Critical one-tail	1,647419	
P(T<=t) two-tail	4,14E-20	
t Critical two-tail	1,963959	
t Stat > t Critical two-tail (9,523904 >1,963959) The null hypothesis is rejected; height growth differs significantly.		

Looking at the overall survival rate of all plantations from 2012 and 2013 until May 2014 (see Table 11), especially for Cuta and Roble a high number of dead seedlings is recorded in the burned forest. Paquió seemed to survive even well in the openness of the burned forest. The best survival is shown by the seedlings of Paquió, planted on skid trails.

TABLE 11: SURVIVAL RATE PER SPECIES AND LOCATION

Species	Undisturbed forest	Skid-trails	Landings	Burned forest	EVERAGE
Cuta	94%	92%	92%	78%	83%
Paquió	92%	99%	97%	91%	93%
Roble	96%	98%	96%	84%	92%

Growth

The plantations which were receiving a lot of direct light (see table 12) showed a satisfactory average height increase of the surviving seedlings.

TABLE 12: ILLUMINATION OF THE ENRICHMENT PLANTINGS

Location	**received light (average)**	
	light class	**description**
Undisturbed forest	3	horizontal
Skid-trails	2	vertical
Landings	1	full
Burned forest	1	full

Average growth rates were significantly lower in the undisturbed forest, where growing conditions were dominated by high amounts of shade under the closed canopy; whereas seedlings on skid-trails, landings and in the burned forest were benefiting from vertical or full light (see table 12 and figure 6). An exceptional growth rate can be shown for the seedlings on landings. Here, the seedlings grew an average of 54 cm during the first six months. The difference in height increase of the seedlings in undisturbed forest and skid-trails was shown to be significant (see table 13).

TABLE 13: VARIANCE TEST FOR GROWTH AFTER 6 MONTHS

t-Test: Two-Sample Assuming Unequal Variances		
Location of enrichment planting	***Skid-trails***	***Undisturbed forest***
Mean	36,01923	7,185606
Variance	880,7957	109,6802
Observations	104	264
Hypothesized Mean Difference	0	
df	113	
t Stat	9,673401	
P(T<=t) one-tail	8,67E-17	
t Critical one-tail	1,65845	
P(T<=t) two-tail	1,73E-16	
t Critical two-tail	1,98118	
t Stat > t Critical two-tail (9,673401 > 1,98118) The null hypothesis is rejected; height growth differs significantly.		

In all locations Cuta was the species with the largest high growth during the first six months. In the burned forest growth differs little between the three species. On landings Roble takes the lead of the highest growth rate in the second year, clearly leaving behind the stagnating growth of Cuta.

FIGURE 6: GROWTH PATTERN OF THE ENRICHMENT PLANTINGS

5.1.3 Section 3: Regeneration in logging gaps and skid-trails

Results of this section are first shown for all identified commercial species and underneath specifically for the three studied species Cuta, Roble and Paquió.

5.1.3.1 Regeneration of all commercial tree species:

Species Composition:

During the study a number of 62 known species were identified (see ANNEX 8). Eleven were classified as commercially high valuable (class 3), nice as commercially intermediate valuable (2 class) (see ANNEX 10) and 41 as without significant commercial value (class 1). This classification was made taking the present use of the species and taking its possible future use by CINAM into account. The five most frequent species which together account for 92 percent of the regeneration, are all pioneer species (see table 14). None of them are of high commercial value. Only for one of the most common species (Sauco Blanco) there might be a possible use for timber production in the future. The regeneration in logging gaps as well as on the skid-trails was clearly dominated by species of non-commercial value (class 1) (see table 15).

TABLE 14: THE FIVE MOST FREQUENT SPECIES FOUND IN LOGGING GAPS AND SKID-TRAILS

Common Name	**Scientific name**	**Commercial value**	**Share of the species on the regeneration in percentage**
Ambaibo	*Cecropia sp.*	1	37%
Pacay cola de mono	*Inga edulis*	1	19%
Sauco Blanco	*Zanthoxylum sp.*	2	16%
Pata de Gallo	*Virola flexuosa*	1	13%
Pacay Rosario	*Inga cytindrica*	1	8%
TOTAL			92%

TABLE 15: COMMERCIAL VALUE OF THE REGENERATION

Commercial value	**logging gaps**		**skid-trails**	
	Nr. of individuals	**Percentage**	**Nr. of individuals**	**Percentage**
1	693	78%	552	78%
2	131	15%	87	12%
3	66	7%	71	10%
TOTAL	890		710	

Nevertheless, in 25 (40%) logging gaps at least one individual with high commercial value was found. 14 (22%) logging gaps were identified without individuals of high commercial value or intermediate commercial value. One logging gap even was without any tree regeneration. On the skid-trails similar representation of commercial tree regeneration was found. Twenty one (33%) skid-trails had at least one individual with high commercial value was recorded and 14 (22%) skid-trials without individuals of commercial value 3 and 2.

It has been observed that the state and composition of the regeneration varied significantly between forest types (see table 16). The number of plots where regeneration of commercially valuable timber species was found was relatively high in high forest and burned high forest. In low forest the total amount of individuals of regeneration as well as the amount of individuals of commercial valuable species was much lower. In the eight logging gaps as well as in the eight skid-trails which were located in low forest which had suffered from a forest fire, no regeneration of species with high commercial value was found.

TABLE 16: PLOTS WITH REGENERATION OF COMMERCIALLY VALUABLE SPECIES

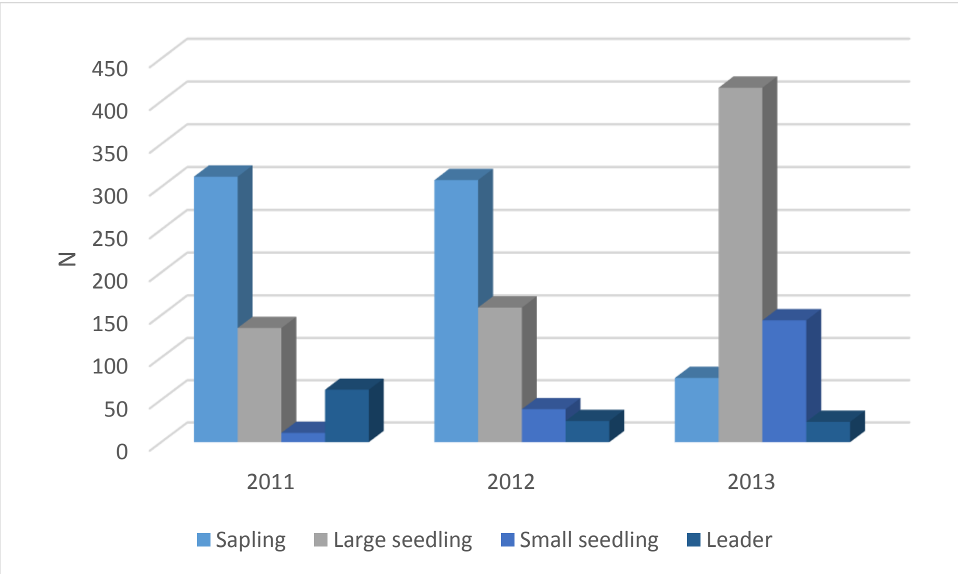
Forest type	Percentage of plots with individuals of commercial value 2 and 3		Percentage of plots with individuals of commercial value 3	
	logging gaps	skid-trail	logging gaps	skid-trail
High forest	83%	75%	69%	58%
Burned high forest	100%	89%	22%	22%
Low forest	36%	73%	0%	45%
Burned low forest	63%	0%	0%	0%

Leader and development trend of the regeneration:

The number of leaders identified in logging gaps from 2013 and 2012 was relatively low (see figure 7). These leaders were trees which had been growing under the canopy of the felled tree. In the logging gaps from the harvesting year of 2011, leaders of the newly established regeneration could be identified. These were all fast growing pioneer species (Sauco Blanco, Serebo, Ambaibo). The composition of the leading trees in older logging gaps is therefore clearly dominated by commercially non-valuable tree species.

In one year old logging gaps a large amount of small seedling were found, whereas in the three years old gaps hardly any small seedling grew under the shade of the large seedling (see figure 7). The distribution of the regeneration by economic value was not shifting significantly during the three years.

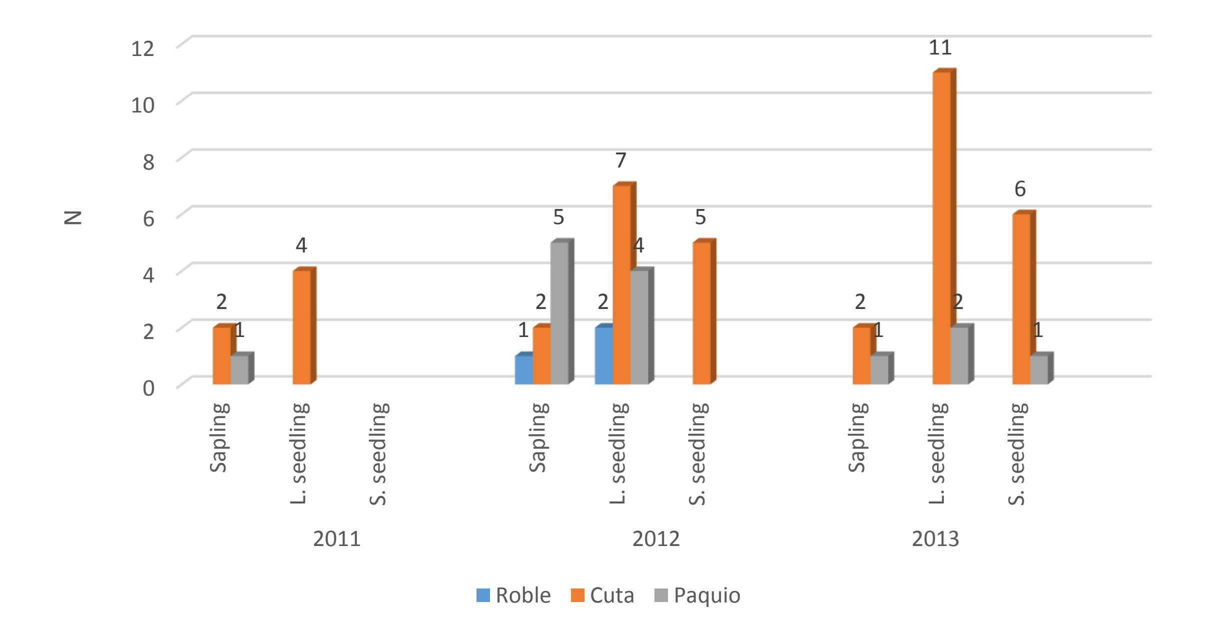
FIGURE 7: SIZE-CLASS DISTRIBUTION OF THE REGENERATION



5.1.3.2 Regeneration of Cuta, Roble and Paquió:

In this section a closer look is given to the regeneration of the three species which are in the focus of this study; Cuta, Roble and Paquió, all of which are classified as commercially high valuable timber species in this study. In total, a number of 38 Cuta, 18 Paquió and two Roble trees were recorded in the logging gaps and skid-trails during the survey. In the following graph a size class distribution is shown separately for harvesting year and species.

FIGURE 8: REGENERATION OF CUTA, ROBLE AND PAQUIÓ PER HARVESTING YEAR AND REGENERATION SIZE



Cuta: During the study plenty of regeneration of the commercially high valuable timber species Cuta was found. High numbers of individuals of the species were recorded in the logging gaps as well as on the skid-trails. Most individuals of the regeneration of this species fall in the size-classes sapling and small seedling. Relatively few trees of higher regeneration were found which can be explained by the generally low regeneration in the plots from the harvesting year 2011. No significantly higher abundance was found in logging gaps were this species had been harvested. Regeneration of the species has been absent in burned low forest and logging gaps of low forest (see table 17 and 18).

Paquió: Regeneration of Paquió has been found mainly on logging gaps were this species had been harvested or on skid-trails were the sample plot was close to a seed tree. As seedlings of this species quickly after germination reach a height of more than 30 cm, only one individual was found of the size-class small seedling (see figure 8). Abundant regeneration of the species has been found in high forest but was absent in the three other forest types (see table 17 and 18).

Roble: Regeneration of Roble has been very rare in the sample plot of the study. Only three individuals in the 126 plots (63 logging gaps + 63 skid-trails) have been identified, all of them in plots of the harvesting year 2012. It could therefore not be shown how the regeneration of this species is developing in the logging gaps during the first three years. In this study, regeneration of this species was also restricted to high forest which had not been burned (see table 17 and 18).

TABLE 17: NUMBER OF INDIVIDUALS OF CUTA, ROBLE AND PAQUIÓ

Skid-trails

Species	High forest	Burned high forest	Low forest	Burned low forest	TOTAL
Cuta	28	2	8		38
Paquio	18				18
Roble	2				2

Logging gaps

Species	High forest	Burned high forest	Low forest	Burned low forest	TOTAL
Cuta	38	2			40
Paquió	15				15
Roble	1				1

TABLE 18: NUMBER PLOTS WERE INDIVIDUALS OF THE THREE SPECIES WERE FOUND

Skid-trails

Species	High forest	Burned high forest	Low forest	Burned low forest	TOTAL
Cuta	13	2	6		21
Paquió	5				5
Roble	2				2

Logging gaps

Species	High forest	Burned high forest	Low forest	Burned low forest	TOTAL
Cuta	16	2			18
Paquió	9				9
Roble	1				1

6 DISCUSSION

6.1 SECTION 1: FUTURE CROP TREES

The purpose of this section of the study is to find out whether the three species Cuta, Paquió and Roble show a sufficient representation by FCTs to secure sustainable harvest in the near future. The results of the study show, that not for all three studied species an equal amount of harvested trees will be available for harvesting of the following cutting cycle in 25 years. Although this study only shows the results of a sampling area of 60 ha and was restricted to one AAA, it shows the complexness of this topic. The findings of this study show that for Cuta, timber yields will already decline in the second cutting cycle. Many forest operators overestimate the growth rate of their harvested species. As in case of the three species studied in this report, most hardwood species in the Amazon forest have a relatively low growth rate. Schulze (2008) shows that a large part of commercial tree species including one of the here studied trees (Paquió) require a recruitment time of at least 60 years.

Calculations were only made using the number of trees, not taking into account their volume. Without further investigations it can be assumed that the volume per harvestable tree is relatively high during the first harvesting intervention but drops abruptly for the second harvest in 25 years. The first harvest includes many trees which have a diameter of more than 70 cm, reducing the stand by almost all bigger trees than DBH 50cm (exception are the remaining 20% seed trees). The growth rates do not allow the forest to recover to its original structure (diameter distribution) within 25 years. This applies for almost all natural forests which are formed into managed forest. It is an intentional process whereas trees are harvested before their increment declines due to age. With these assumptions even less wood of the currently harvested species is available for the following cycles.

6.2 SECTION 2: EVALUATION OF ENRICHMENT PLANTINGS

The success of enrichment plantings depend on various aspects, some of which have been treated in this report. The results of the evaluation of the enrichment plantings show that in general seedlings of all three species are growing well in the enrichment plantations. Seedlings planted in undisturbed forest show a lower growth rate than in the other locations, but are still surviving well. Not included in this study but observed in the field is that competing vegetation (mainly lianas) which have to be removed regularly from the seedlings is much lower in the undisturbed forest than in all other plantations and therefore lowering the costs for tending of the seedlings.

The plantation in the burned forest is dominated by a high mortality rate. This is due to the low canopy cover of the location. Planted seedlings that received direct sun during the whole day were suffering from a planting shock. It appears that many of the seedlings could not cope with the harsh conditions (no shade) in the burned forest. This is shown by the relatively high mortality rate during the first months, whereas in a late state few seedlings are dying. To reduce the mortality in these plantations, seedlings have to be hardened in the nursery before they are planted outside, even if the enrichment planting happens during the rainy season.

The selection of planting sites was done manly randomly and not taking into account environmental conditions. During the study it was also observed, that seedlings would not grow similarly well or bad in all landings. The growth seemed to differ very much depending on different soil types (personal observation by the author). What the company also did not consider before planting the seedlings was a study of the natural regeneration of the specific sites. In section 3 it has been shown, that the natural regeneration differs very much according to different vegetation types. During the evaluation it was observed, that in almost all of the sites where seedlings of the species Cuta were planted, natural regeneration of the same species was present in a sufficient amount and a better shape than the planted seedlings.

6.3 Section 3: Regeneration in logging gaps and skid-trails

The purpose of this section of the study was to find out if the regeneration of commercial timber species, in particular of Cuta, Roble and Paquió, in logging gaps and skid-trails is sufficient to justify liberation of natural regeneration as a silvicultural treatment. The findings of this study show that tree regeneration in logging gaps and skid-trails is weighted towards aggressive pioneer and other fast-growing lightwood species, the former of no economic value and the latter typically of low timber value. Similar findings are shown by previous studies carried out in Bolivian tropical forests. Fredericksen, et al. (2000) state that selective harvesting of commercial species leads to a proportionate increase in seedlings of non-commercial species. Two main factors seem to be the reason for this change in forest composition. The loss of seed trees of commercial species as mature trees are removed from the stand, especially if harvesting is carried out in advance of seed production, is one of them. An additional factor responsible for regeneration problems is the aggressive colonization of clearings by non-commercial species.

In this assessment it has been observed that the state and composition of the regeneration varied significantly between forest types. In the high forest there appears to be sufficient regeneration of commercially high valuable tree species to implement liberation treatments. By the identification of leading individuals in the logging gap it is shown, that without intervention light wooded pioneer species which are not of commercial value for the company will take over the lead in the succession of the logging gaps and the skid-trails. As a large proportion of forest regeneration in selectively logged forest will occur in logging gaps it would result in a shift of species composition from high value species (with dense wood) towards lightwood (plywood grade species). Thus leading to a severe population decline of certain high value timber species. Hence, it is important to apply silvicultural treatments to manipulate the natural succession. Various authors (Fredericksen, et al., 2000), (Fredericksen, et al., 2001), (Pariona, et al., 2013), (Mostacedo, et al., 1990) have pointed out the necessity to control non-commercial species in logging gaps. According to Fredericksen, et al. (2000) silvicultural treatments, such as mechanical cleaning or herbicide treatments could be applied to control competing vegetation and accelerate the growth of commercial tree regeneration. Schwartz et al. (2013) are emphazising the adventages of tending naturally established seedlings/saplings of commercial species in logging gaps in comparison to enrichment planting. The tending treatment showed lower mortality rate, faster growth rate, and required less liberation from overstorey plants and lianas than the enrichment planting (Schwartz, et al., 2013).

In burned high forest, low forest and burned low forest the number of plots were regeneration of commercially high value timber species was found are relatively low. It might be too costly to find enough individuals which can be supported to justify liberation treatments. Here, it seems appropriate to implement enrichment planting to secure the regeneration of commercial tree species.

To guarantee the regeneration of Cuta and Paquió in the FMU, sufficient natural regeneration in at least one forest type is found to justify liberation treatments. Especially for Paquió, of which most regeneration was found were the same species was cut, liberation treatments could be organized well, keeping the costs low. Liberation treatments could be applied were mature trees of this species had been harvested. The regeneration of Cuta could easily be supported by liberation treatments in almost all sites, making the costly enrichment planting of this species unnecessary.

The regeneration of Roble is a more delicate topic. Like it had been shown in other forests of Bolivia, also in this study the natural regeneration of Roble had been found extremely low and even absent in many of the sites where trees of this species are harvested. Especially in low forest where its density of mature trees is naturally much higher than in the high forest, no regeneration was recorded. There is not enough natural regeneration of this species to support its recruitment in logging gaps or skid-trials by liberation treatments. To secure the regeneration of Roble CINMA might even consider installing additional enrichment plantings in logging gaps.

7 Conclusions and Recommendations

During this study a number of important findings have been made about the regeneration of the three studied species but it has also shown the need for further research in this area. To secure sustainability in the management of the FMU of CINMA more knowledge has to be gained on growth patterns of the studied species. To be able to implement well directed silvicultural treatments it would be important to make further investigations about soil and vegetation types in the FMU. With sophisticated site maps, the company could implement differentiated management practices. Nevertheless, a few conclusions for improvement of the management practices can be drawn from this study. The results from section 1 reinforce the need for the discussion of longer cutting cycles and harvesting intensity (possibly by changing the minimum cutting diameters). Considering the different growth patterns of tree species, the implementation of species specific MCD should be implemented. A differentiation has to be made in the management of faster growth species and species which show very low growth rates. Another option to reduce the pressure on the few high-value species is to open up new markets for timber tree species which are currently not harvested. With the use of additional species the pressure on species like Cuta, Roble and Paquió could be reduced significantly. The high costs of pre-harvesting activities (census and liana cutting) of the applied management system do not allow companies like CINMA to reduce their harvesting volume per hectare. The harvesting volume of the company which today consists of five different species could include a higher number of species in the future. Villegas et al. (2008) suggest that in Bolivia the number of 20 species which are exploited for their timber today could be increased to 50 species in the future. The results of this study show, that the process of opening up new markets for unknown timber species is indispensable in the long term. Even during the second cutting cycle the company will not be able to extract the same volume of the high-value timber species compared to present harvesting interventions.

Nevertheless, forest operators in Bolivia will not be able to apply post-harvesting silvicultural treatments to increase the number of valuable trees. Silvicultural treatments have to be firmly anchored in future management plans. Treatments have to be applied in a cost-effective and species specific manner. It will not lead to a satisfactory result if in one FMU all tree species are treated the same way regardless of its growth patterns and response to additional light. Several silvicultural treatments are available positively affecting a better regeneration of the high value timber species but also supporting the growth of the already existing stands which will serve as timber for the next two cutting cycles.

To secure enough regeneration of commercial timber species in the more distant future, different management tools can be applied. In section 2 and 3 it was shown, that for the application of the different silvicultural treatments, a differentiation has to be made by species and forest type. Were enough natural regeneration of commercial timber species is available, liberation treatments are appropriate. Nevertheless, in areas like the studied burned forest were regeneration of commercial tree species was very scarce, additional enrichment planting is indispensable to secure sustainable yields in the future. Both treatments should be applied simultaneously within the same management area, tending available regeneration wherever possible, and planting species that are adapted to local conditions whenever needed.

A few recommendations can be made for enrichment planting. For the survival of the seedlings it is of great importance that during the first two to three years competing vegetation is removed regularly. To determine the intervals of the clearing it might be necessary to conduct further studies.

Nevertheless, the author is recommending to clean plantations in the undisturbed forest once a year whereas in the other plantations were competing vegetation is much higher, it might be necessary to remove competing vegetation twice per year.

Finally, it can be said, that CINMA has to add additional silvicultural treatments in their management scheme. Additional silvicultural treatments like liberation of regeneration and enrichment planting have to be installed in the permanent management plan. As with the selection of seed trees, post harvesting treatments have to be applied on entire AAA. For an adequate regeneration it is not sufficient if treatments are only applied on trial basis, covering only fractions of the managed forest. In order to identify the most cost-effective methods of liberation, planting, cleaning etc. it is necessary to conduct additional studies.

A big challenge with almost all silvicultural treatments is that they entail substantial investments that will not pay financial dividends for many decades. The bigger companies in Bolivia like CINMA would be able and willing to invest in the forest regeneration if they could be certain that they will keep the concessional rights over the next century. Here, it is the task of the government to find adequate agreements with the concessionaires which will give them confidence to make investments on land which is still owned by the state. Unfortunately, concessionaries in Bolivia are still under legal uncertainty. With the transformation of all concessions in Bolivia into Special Temporary Authorization (Autorización Transitoria Especial, ATE) in December 2010, the government increased its control over the management but also intimidated concessionaries in their investment planning. When authorization is only given temporarily the companies are not likely to invest in additional silvicultural treatments.

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9 APPENDICES

9.1 ANNEX 1: NATURAL REGENERATION IN THE FMU

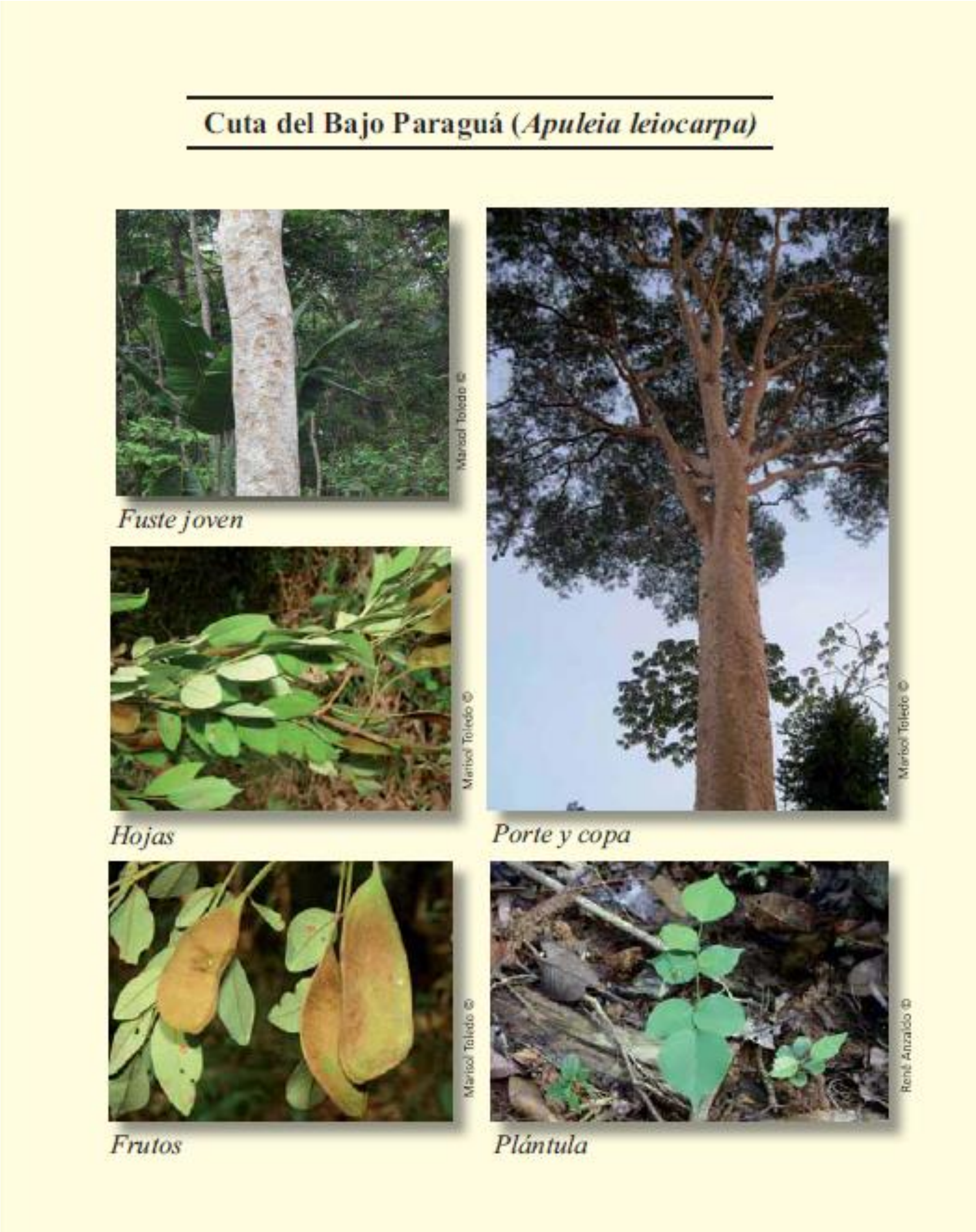
FIGURE 9: RESULTS FROM THE FOREST INVENTORY FOR THE REGENERATION IN THE FMU (COPIED FROM (CINMA, 2014)

ESPECIE	ABUNDANCIA TOTAL POR CATEGORIA DE RN				RESULTADOS PROMEDIOS POR HA			
	BRINZAL	LATIZAL	FUSTAL	TOTAL	BRINZAL/ha	LATIZAL/ha	FUSTAL/ha	TOTAL/ha
AMARGO	1	0	8	**9**	10	0	3.2	**13.20**
CAMBARA MACHO	16	3	6	**25**	160	4.8	2.4	**167.20**
BIBOSI	2	0	1	**3**	20	0	0.4	**20.40**
BLANQUILLO	24	7	10	**41**	240	11.2	4	**255.20**
CAMBARA	20	4	3	**27**	200	6.4	1.2	**207.60**
CUTA	14	0	6	**20**	140	0	2.4	**142.40**
GUAYABOCHI	6	1	3	**10**	60	1.6	1.2	**62.80**
JICHITURIQUI	2	0	5	**7**	20	0	2	**22.00**
MANICILLO	2	5	21	**28**	20	8	8.4	**36.40**
MARA	0	1	0	**1**	0	1.6	0	**1.60**
MARFIL	8	4	4	**16**	80	6.4	1.6	**88.00**
MURURE	29	8	23	**60**	290	12.8	9.2	**312.00**
NEGRILLO	19	4	5	**28**	190	6.4	2	**198.40**
NUI	79	27	66	**172**	790	43.2	26.4	**859.60**
PAQUIO	0	1	2	**3**	0	1.6	0.8	**2.40**
PICANA	7	1	5	**13**	70	1.6	2	**73.60**
PIRAQUINA	35	2	13	**50**	350	3.2	5.2	**358.40**
ROBLE	0	0	10	**10**	0	0	4	**4.00**
SAUCO BLANCO	1	2	9	**12**	10	3.2	3.6	**16.80**
OTRAS ESPECIES	626	203	396	**1225**	6260	324.8	158.4	**6743.20**
TOTAL	**891**	**273**	**596**	**1760**	**8910**	**436.8**	**238.4**	**9585.20**

The table above is showing the results of the forest inventory for the regeneration in the FMU. Listed are all species which are currently harvested and which have a potential to be harvested in the future. The abundance is shown in total (Abundancia Total) and in average per hectare (promedio por ha). The regeneration was listed in size-classes: Brinzal (<150cm), Latizal (>=150cm, <10m), Fustal (height >= 10m, DBH < 20cm). Orange underlined are the species which show a poor regeneration, in blue species which have regular regeneration and in green species which have good regeneration.

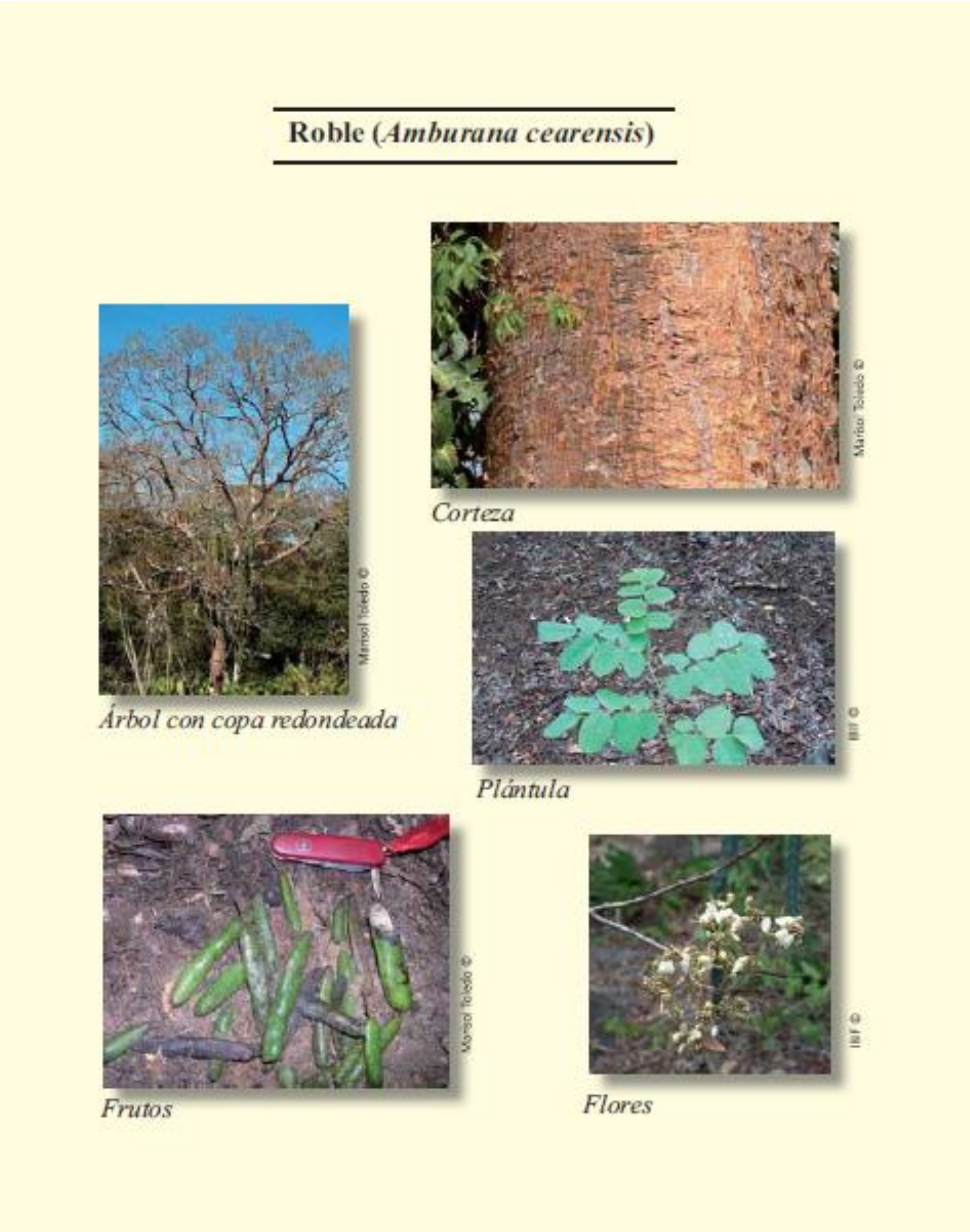
9.2 ANNEX 2: ILLUSTRATIONS OF CUTA (*APULEIA LEIOCARPA*)

FIGURE 10: ILLUSTRATIONS OF CUTA, SOURCE: (VILLEGAS, ET AL., 2008)



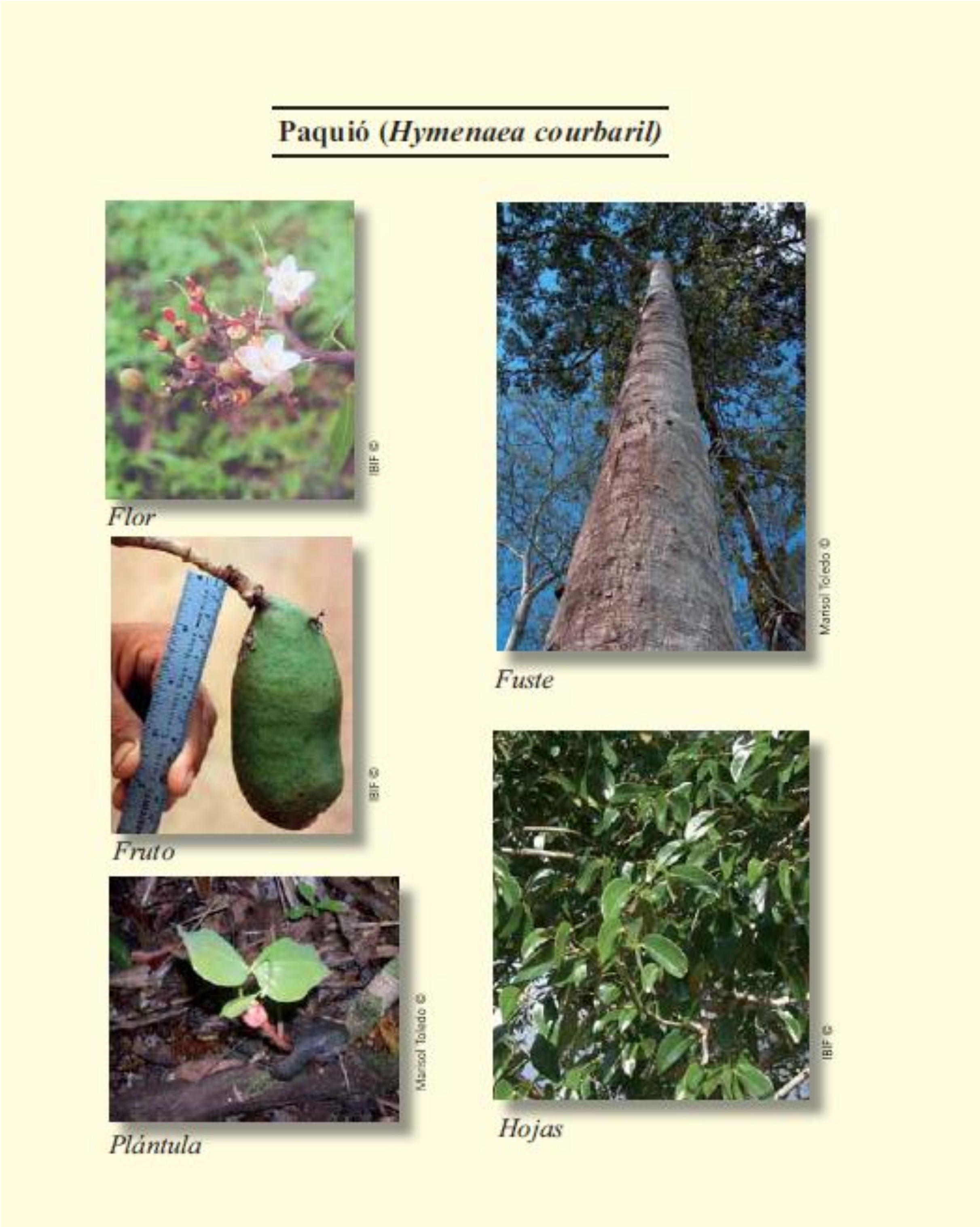
9.3 ANNEX 3: ILLUSTRATIONS OF ROBLE (*AMBURANA CEARENSIS*)

FIGURE 11: ILLUSTRATIONS OF ROBLE, SOURCE: (VILLEGAS, ET AL., 2008)



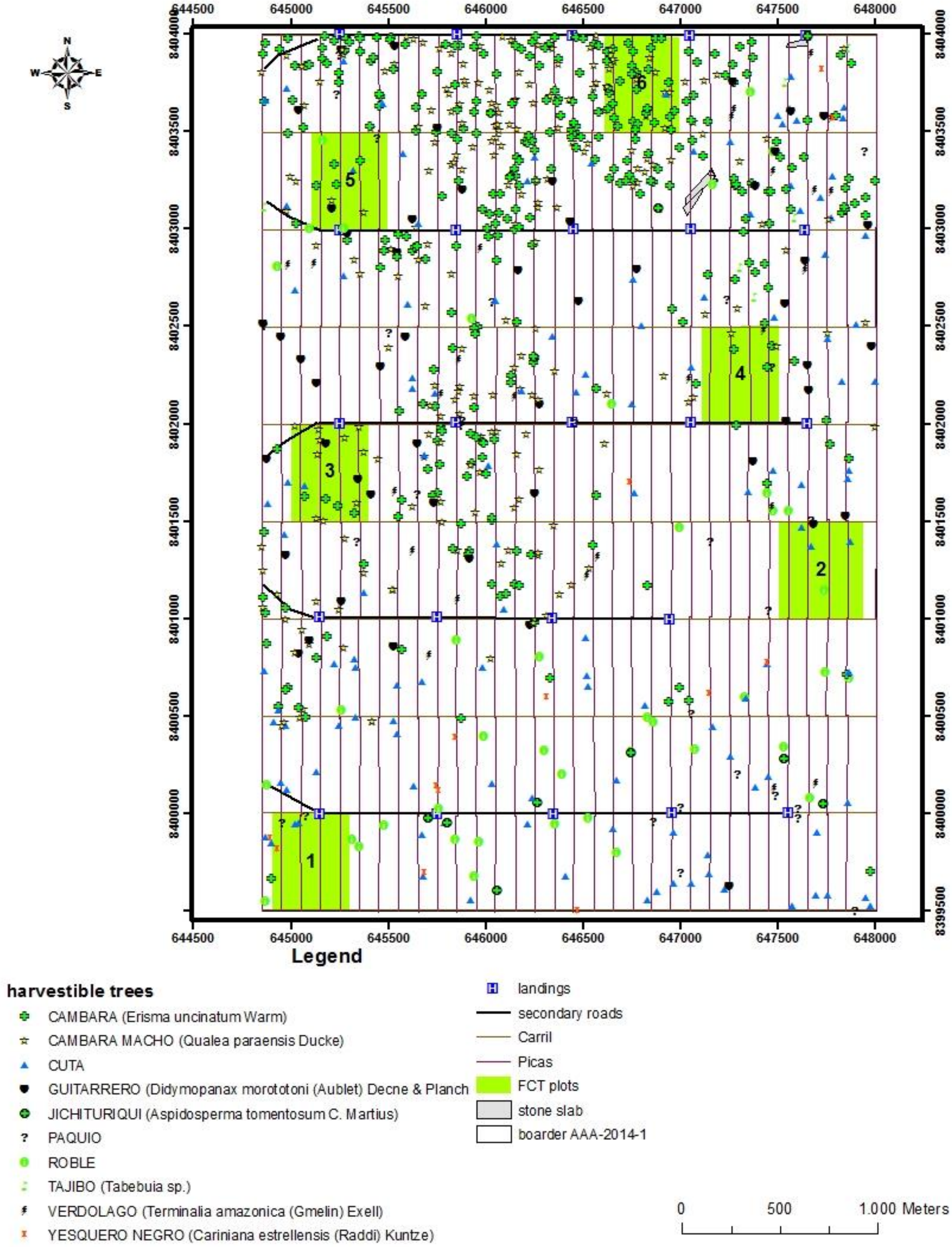
9.4 ANNEX 4: ILLUSTRATIONS OF PAQUIÓ (*HYMENAEA COURBARIL*)

FIGURE 12: ILLUSTRATIONS OF PAQUIÓ, SOURCE: (VILLEGAS, ET AL., 2008)



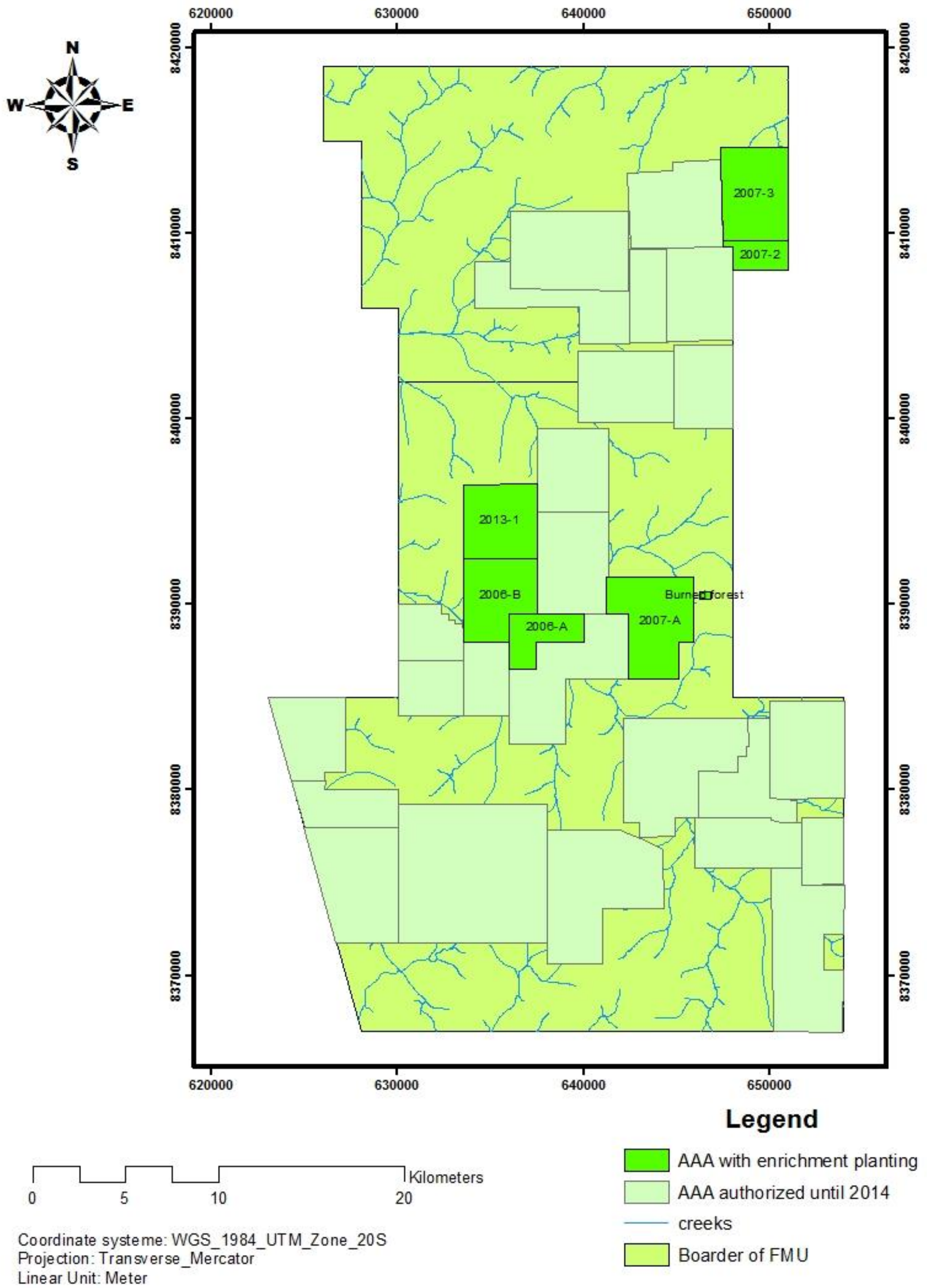
9.5 ANNEX 5: DISTRIBUTION OF FCT PLOTS IN THE AAA-2014-1, *LOS CALAMBRES*

FIGURE 13: MAP OF THE LOCATION OF FCT PLOTS IN THE AAA-2014-1, *LOS CALAMBRES*



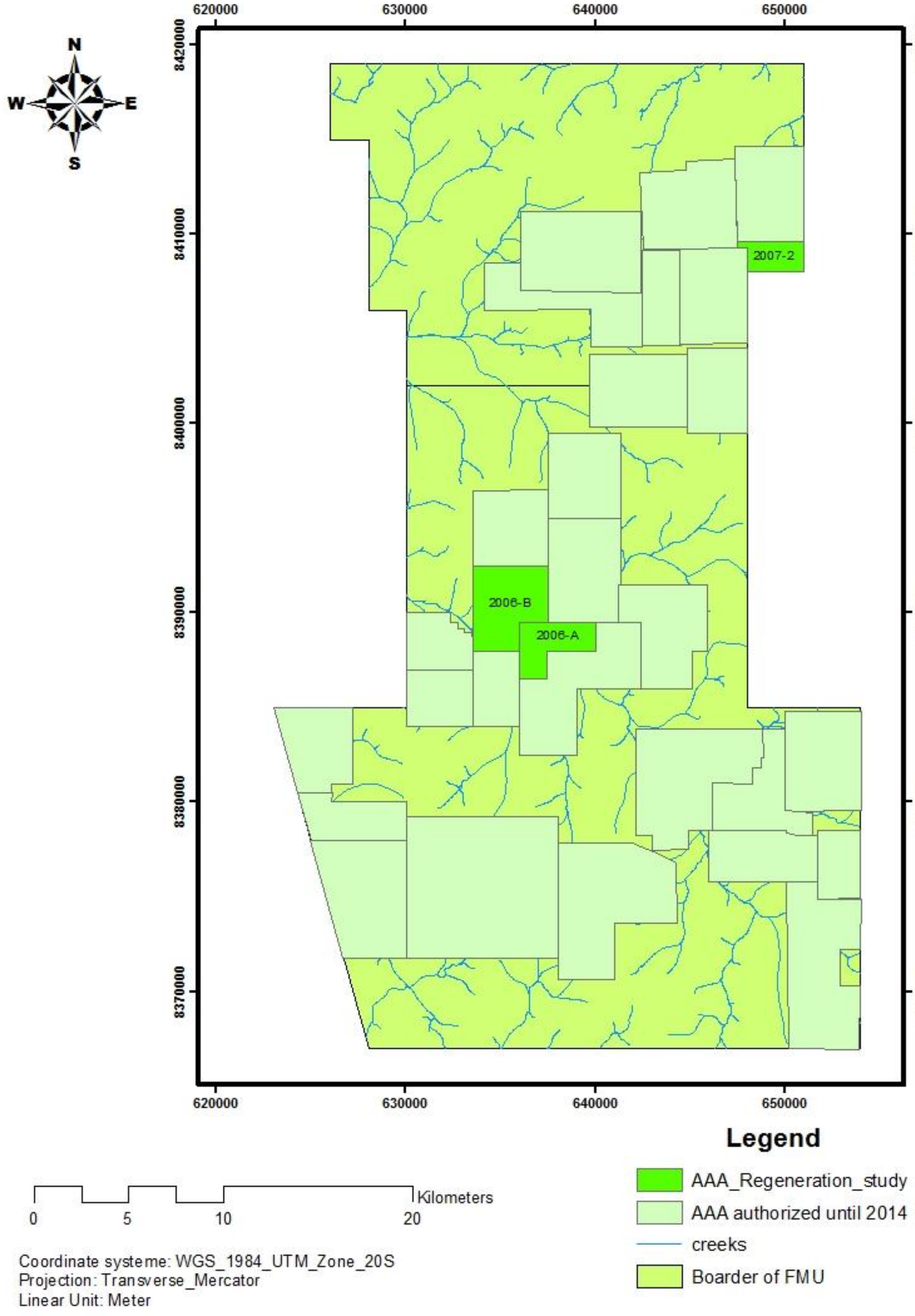
9.6 ANNEX 6: LOCATION OF ENRICHMENT PLANTINGS

FIGURE 14: MAP OF THE LOCATION OF ENRICHMENT PLANTINGS WITHIN THE MANAGEMENT UNIT



9.7 ANNEX 7: LOCATION OF AAA FOR REGENERATION STUDY

FIGURE 15: MAP OF THE LOCATION OF AAA FOR REGENERATION STUDY



9.8 ANNEX 8: SPECIES FOUND IN LOGGING GAPS AND SKID-TRAILS

TABLE 19: LIST OF SPECIES FOUND IN LOGGING GAPS AND SKID-TRAILS

Common Name	**Scientific name**	**Commercial value**
Amargo	*Simarouba sp.*	3
Ambaibo	*Cecropia sp.*	1
Bibosi	*Ficus sp.*	1
Blanquillo		1
Cabeza de Mono	*Apeiba tibourbou*	1
Cafecillo		1
Cambara	*Erisma uncinatum*	3
Cambara dos		1
Cambara Macho	*Qualea paraensis*	3
Cari Cari Blanco	*Acacia sp.*	1
Cari Cari Bravo	*Acacia sp.*	1
Carne de Toro	*Combretum leprosum*	1
Cedrillo	*Spondias sp*	1
Cedro	*Cedrela fissilis*	3
Coco	*Guazuma ulmifolia*	1
Coloradillo		1
Conservilla	*Amaioua sp*	1
Cuse	*Casearia gossypiosperma*	1
Cuta	*Apuleia leiocarpa*	3
Gabetillo	*Simira rubescens*	1
Gabetillo dos		1
Gargatea	*Jacaratia sp.*	1
Guayabochi	*Calycophyllum spruceanum*	1
Guitarrero	*Didymopanax morototoni*	3
Huevo de Perro	*Tabernaemontana cymosa*	1
Jichituriqui	*Aspidosperma sp*	2
Leche Leche	*Sapium sp.*	1
Lucuma	*Pouteria macrophylla*	1
Mafil	*Liciana sp.*	1
Manicillo	*Sterculia sp*	2
Mela		1
Mora	*Maclura tinctoria*	1
Murure	*Brosimum acutifolium*	2
Negrillo	*Machaerium sp.*	1
Nui	*Pseudolmedia laevis*	1
Ojoso Negro	*Pseudolmedia laevis*	2
Pacay	*Inga sp.*	0
Pacay cola de mono	*Inga edulis*	1

Pacay Rosario	*Inga cytindrica*	1
Pama	*Pseudolmedia sp.*	1
Paquió	*Hymenaea courbaril*	3
Pata de Buey	*Bahuinia sp*	1
Pata de Gallo	*Virola flexuosa*	1
Piraquina	*Xilopia sp.*	1
Piraquina Verde	*Xilopia sp.*	1
Picana	*Cordia alliodora*	1
Piton	*Talisia esculenta*	1
Plumero	*Vochysia lancelata*	2
Quavo		1
Roble	*Amburana cearensis*	3
Sahuinto		1
Sauco Blanco	*Zanthoxylum sp.*	2
Sauco Negro	*Zanthoxylum sp.*	1
Serebo	*Schizolobium amazonicum*	2
Suca	*Spondias mombin*	2
Tajibo	*Tabebuia sp*	3
Tarumacillo	*Vitex sp.*	1
Toborochi	*Chorisia sp.*	1
Toco Negro	*Enterolobium sp.*	2
Uvilla	*Trema micrantha*	1
Verdolago	*Terminalia amazonica*	3
Yesquero Negro	*Cariniana estrellensis*	3

9.9 ANNEX 10: FREQUENCY OF SPECIES OF HIGH COMMERCIAL VALUE AND INTERMEDIATE COMMERCIAL VALUE

TABLE 20: SPECIES OF HIGH COMMERCIAL IN LOGGING GAPS AND SKID-TRAILS

Species		**skid-trails**				**Logging gaps**				**TOTAL**
Common name	**Scientific name**	Small seedling	Large seedling	Sapling	TOTAL	Small seedling	Large seedling	Sapling	TOTAL	
Amargo	*Simarouba sp.*	4		2	6	1		1	2	**8**
Cambara	*Erisma uncinatum*		1		1		2	1	3	**4**
Cambara Macho	*Qualea paraensis*			2	2			1	1	**3**
Cedro	*Cedrela fissilis*						1		1	**1**
Cuta	*Apuleia leiocarpa*	7	3	11	21	4	3	11	18	**39**
Paquio	*Hymenaea courbaril*		2	3	5	1	5	3	9	**14**
Roble	*Amburana cearensis*		1	1	2			1	1	**3**
Tajibo	*Tabebuia sp*							1	1	**1**
Yesquero Negro	*Cariniana estrellensis*		1		1			1	1	**2**

TABLE 21: SPECIES OF INTERMEDIATE COMMERCIAL VALUE IN LOGGING GAPS AND SKID-TRAILS

Species		**skid-trails**				**Logging gaps**				**TOTAL**
Common name	**Scientific name**	Small seedling	Large seedling	Sapling	TOTAL	Small seedling	Large seedling	Sapling	TOTAL	
Jichituriqui	*Aspidosperma sp*	1	1		2			2	2	**4**
Manicillo	*Sterculia sp*	1	1	1	3		3		3	**6**
Murure	*Brosimum acutifolium*		2	2	4	2	2	5	9	**13**
Ojoso Negro	*Pseudolmedia laevis*		2		2		2	1	3	**5**
Sauco Blanco	*Zanthoxylum sp.*	5	10	8	23	4	22	10	36	**59**
Serebo	*Schizolobium amazonicum*		3	3	6		8	6	14	**20**
Suca	*Spondias mombin*	1			1		1		1	**2**
Toco Negro	*Enterolobium sp.*	1	1	2	4		1	2	3	**7**