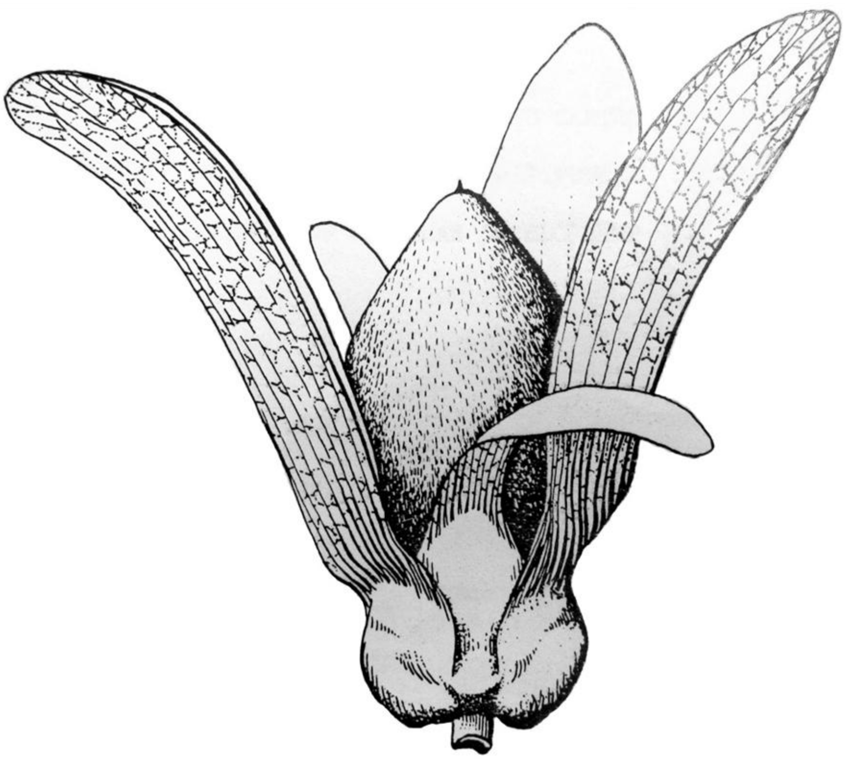
2013

The Illipe nut (Shorea spp.) as additional resource in plantation forestry

Case Study in Sarawak, Malaysia



Quirijn Coolen

Van Hall Larenstein, University of Applied Sciences

Bachelor Thesis

Student nr. 890102002

The Illipe nut (*Shorea spp*.) as additional resource in plantation forestry

Case study in Sarawak, Malaysia

Quirijn T. Coolen

Bachelor Final Thesis 2013
Course: Tropical Forestry
Student number: 890102002
January 1, 2014

Project supervisor Sarawak Forestry Department: Mr. Malcom Demies

Cover photo: Nut, *Shorea macrophylla* (Connell, 1968)

"One, and only one incentive sends Sarawak Malay women deeply into the jungle. Not regularly, - but otherwise unique, is either one of two kinds of nut which fruit irregularly – but when they do in such profusion that every man, woman and child can usefully turn out to help reap these strictly "cash crops" in the coastal fringe."

(Harrisson & Salleh, 1960)

Acknowledgments

I would like to acknowledge the support of the Van Hall Larenstein University, the Sarawak Forestry Department and the Sarawak Forestry Corporation for their approval and help on the completion of my Thesis study under their supervision.

This report could not have been completed without the help of the following people in particular, to whom I want to express my greatest thanks; Dr. Peter van de Meer, who initiated the contact between the Sarawak Forestry Department and the Van Hall Larenstein University and was my personal supervisor from the latter, encouraging me to broaden my perspective on the subject and improve when necessary. Special thanks to my study and project partner, Jorn Dallinga, who traveled with me to Malaysia and with whom I shared the experience and work in the tropical Sarawak forests. Furthermore I would like to thank Mr. Malcom Demies, who was my project supervisor from the Sarawak Forestry Department and who helped me getting started with the subject as well as the inventory in the Semengoh forest during a period when he was exceptionally busy.

Furthermore I would like to thank Dr. Ernest O. K. Chai and Dr. Hua Seng Lee, who have both shared their knowledge and time with me to help me gather information on the subject, but also introduced me to local customs, of which I still treasure good memories. Finally, I would like to thank the staff of the Sarawak Forestry Library with Ms. Doreen Ang in particular and other people who directly and indirectly helped me with completing my thesis.

Abstract

This report is the product of a Bachelor Thesis study on the production capacity of the Illipe nut in a *Shorea spp.* plantation forest. The study is executed by Quirijn Coolen under the supervision of Van Hall Larenstein, University of Applied sciences in the Netherlands and hosted by the Sarawak Forestry department. The study comprises a literature research combined with a field inventory performed in the Semengoh Forest Reserve in Sarawak, Malaysia.

The study was conducted not only to explore and summarize the current knowledge on Illipe nuts, but also to link this knowledge to an example area in the Sarawak region, in order to prove the additional value of this product. The inventory was held in a plantation situated in the Semengoh Forest Reserve, established by the Sarawak Forestry Department during the period 1926-1940 to determine the potential for production of *Meranti* timber and Illipe nuts. The *Shorea spp.* involved in the inventory are; *S. macrophylla, S. splendida, S. pinanga, S. stenoptera, S. palembanica,* and *S. hemsleyana*. The literature resources used in this study were collected with help from the Sarawak Forestry Library and the use of electronic documents. It can be seen as a very complete list of available literature on the topic of Illipe nuts in Sarawak.

When calculating the potential of Illipe nuts in plantation forests, crop yields very much depend on various parameters such as the intensity of the crop, which is subject to the mast flowering known to Dipterocarps, spacing of the trees in a plantation, sub-species of Shorea and soil type. The yield potential of Illipe nuts in Sarawak has been presented in this report using 3 different yield figures, divided in a low, moderate and optimal model, each using different parameters. The potential yield of (dry) Illipe nuts per hectare is approximately 348kg, 953kg, and 3.200 kg respectively. However, actual yields differ greatly depending on plantation characteristics.

This study furthermore summarizes the efforts involved with the (traditional) collection, the processing methods and use of Illipe nuts in Sarawak. The export quantities and the value of the Sarawak Illipe nut over time are also mentioned. Finally, the most important Illipe nut producing Shorea species are presented, accompanied by a variety of species that are also known to produce nuts.

Keywords: Illipe nuts; Shorea; Plantation forest; Sarawak; NTFP.

Contents

List of Tables and Figures

Tables

Figures

1. Introduction

Sarawak is the Malaysia's largest state, and shares the island of Borneo with Sabah (Malaysia), Kalimantan (Indonesia) and Brunei. Its climate is typical of the equatorial belt, with high rainfall (well over 2.500mm) and humidity, but moderate temperatures (23°C average in Kuching). It rains all year round, but more heavily during the north-east monsoon November-March (Smythies, 1960). Borneo is the stronghold of the Dipterocarpaceae, and the forests are dominated by members of this family, totaling about 300 species (many new ones are in the process of being described). The flora has close affinities with Malaya, having been connected to it by the Sunda shelf during periods of the Pleistocene glaciation. (Smythies, 1960)

The family Dipterocarpaceae dominates many of the species-rich, lowland tropical rainforests of the aseasonal Western Malesian region (Ashton, 1964). In some forests, the Dipterocarps may account for as much as 10% of all the tree species and 80% of all the emergent individuals (Ashton, 1982). As a family of plants, the Dipterocarpaceae might be the most well-known trees in the tropics. These tall canopy trees are so important, that they even have their own vegetation zone named after them; the Dipterocarp forests (Appanah & Turnbull, 1998).

Dispersal of Dipterocarps

In the Malesian region 10 to 14 Genera of Dipterocarps are present, including 465 species. On Borneo, 13 Genera of Dipterocarps are present, including 267 species of which 58% is endemic to the island. (Appanah & Turnbull, 1998).

TABLE 1. HABITAT RANGES OF DIPTEROCARPS IN PENINSULAR MALAYSIA (APPANAH & TURNBULL, 1998)

0-300m.	Low undulating Dipterocarp forest
300-750m.	Hill Dipterocarp forest
750-1200m.	Upper Dipterocarp forest

These Asian Dipterocarps occupy a large variety of habitats, occurring in coastal, inland, riverine and swampy areas, as well as dry lands, growing on undulating or leveled terrains, as well as ridges, slopes, valley bottoms. They grow on deeply weathered to shallow soils, well drained to poorly drained and rich to poor nutrient availability (Symington, 1943). In Peninsular Malaysia, altitudinal zonation is applicable on the main habitat ranges of Dipterocarps, as seen in Table 1.

FIGURE 1. THE ISLAND OF BORNEO. EDITED BY Q. COOLEN

However, these ranges are not applicable on Borneo. Here, Dipterocarp habitat zones differ based not only on altitude, but also in conjunction with other natural barriers, such as large rivers and watersheds. The freshwater swamps are rich in species, especially in the drier parts, but the true peat swamps are relatively poor, same as limestone and some riverine fringes (Symington, 1943). The Northwest and Northeast of Kalimantan, including Sarawak, Brunei and Sabah, are much richer in species than the rest of Kalimantan (Appanah & Turnbull, 1998).

Origen of the name Illipe

The term "Illipe nut" was originally derived from the Tamil names for the nuts of Bassia spp. of the family Sapotaceae in South India (Anderson, 1975). Tamil names for these nuts of mainly Bassia longifolia included; "Illupia", "Illupei" and "Illipi". Furthermore the name Illipe was used for Mourak nuts (Bassia latifolia) from the same region and Siak nuts (Palaquium oleosum and Palaquium oblongifolium) from Sumatra (Connell, 1968).

It is likely that the term "Illipe" then found its way to Borneo, where it was applied to the oil bearing nuts from some members of the Shorea family (Anonymous, 1915). Because of the importance as a commodity, the name "Illipe" is now commercially linked to the Illipe nut of the Shorea family and the widely accepted term for the nuts in the Sarawak and Borneo region.

As this study will be solemnly focused on the Illipe nuts from the Shorea family, the name Illipe will only be used in resemblance of these species. Although Illipe is the commercially used name for Illipe nuts of Shorea spp., local names are used more frequently in the main producing regions, which are Sarawak, Brunei, Sabah and West Kalimantan, Indonesia (Stanton, 1992). "Engkabang" is the general accepted term for Illipe in Sarawak, but names may vary upon region or ethnicity. The Illipe nut (referring to the fruit itself) is locally known as 'Engkabang', 'Abang' or 'Kawang' in Sarawak and 'Sengkawang' or 'Singkawang' in Kalimantan. The Iban even make a difference between the larger nuts (Engkabang) and the smaller ones (Lelanggai). Apart from the (local) names to describe the Illipe nuts, other names are known to describe the product of the nuts, the Illipe oil or butter. Commonly the Malay translation for fat or oil is 'Minyak tengkawang' but other names include 'Tangkawan' and 'Kakowang'. The shelled nuts are sometimes called 'Padi tengkawang' (Anonymous, 1915). Illipe nuts have since long been an important export product for Sarawak, reaching its high point in the period between 1953 and 1962, when it became one of the major export products, shipping as much as 22.000 tonnes in 1959, (Connell, 1974) partially because of the increased price for cacao butter (Wong, 1988).

At the moment, Dipterocarps dominate the international tropical timber trade where they are well valued for their timber (Meranti) and facilitate a substantial part in the economy of many Southeast Asian countries and also contribute important timbers for domestic needs (Appanah & Turnbull, 1998). As demands for valuable hardwood timber are rising, the pressure on the forests of Borneo and elsewhere is increasing. Timber of the species Shorea spp., usually referred to as Red Meranti, has long been one of the major export products of Sarawak, Sabah and Kalimantan, but natural stands of these trees are now scarce (Blicher-Mathiesen, 1994). In addition, Dipterocarp forests provide a variety of (lesser known) forest products on which many forest communities depend for their survival, such as resins and oils (*Damar* and *Camphor*) and traditional medicines. One of these products is the seed kernel of a Dipterocarp member producing the red Meranti timber, *Shorea spp*. This study will focus on the potential of these nuts in the Sarawak region of Malaysia.

The seed kernels of these Shorea species are collected as a well valued forest product, but only a few are capable of producing nuts large enough to be worth collecting (Smythies, 1958).

The seed kernel of about 9-10 sub-species of Shorea are mainly collected in the forest, although some domestication of trees also occurs (Chin, 1985); (Connell, 1974). In Sarawak, around 90% of the collected seeds originate from the subspecies *Shorea macrophylla*, which is, together with *S. stenoptera* the most well-known for its seed kernels (Blicher-Mathiesen, 1994); (Chin, 1985). The preference for species largely depends on ease of collecting, oil content and individual size of the seeds (Connell, 1974).

Shorea species flower and produce seeds on an irregular interval. This mast fruiting, in much South-east Asian literature called general fruiting usually occurs every 3-4 years after a period of several rainless weeks (Ashton, Manual of the Dipterocarp trees of Brunei State, 1964). This irregular flowering and fruiting is a major problem in the Illipe nut production and causes great price fluctuations over the years. Together with the fast germination of the seeds and the infestation of seed predators, the seed collection is hard to be planned. Although the mast flowering stresses the potential of the Illipe nut as an export product, (Anderson, 1975) described a local species from Kalimantan, *Shorea stenoptera* forma Burck, to be flowering annually and from a very early age (2.5 years), that could solve this problem.

Because Shorea spp. and their products have been and continue to be of economic importance for Sarawak, the Sarawak Forestry Corporation has requested a study on the potential of the Illipe nut, of which this report is the result. In the past, several studies are performed on the characteristics of Shorea spp. in Sarawak and other regions. However, an overview of the current status of this product is lacking and up to date knowledge is hard to find. This study will present a clear overview on the history of this interesting forest product and study the potential it has as a domestic and export product, such as a substitute for cacao butter and cosmetic products (Lipp & Anklam, 1998; Blicher-Mathiessen, 1994).

The study integrates literature resources with a field based example, to show the potential by calculating the productivity on an existing area. The field data will be collected in the Semengoh forest reserve in West Sarawak, where several *Shorea spp*. plantation plots are present, initially planted by the Sarawak Forestry department (SFD) from 1926 to 1940, to research the potential of plantation (Dipterocarp) forests and their products. The plots contain 6 sub-species of Shorea; *S. macrophylla*, *S. pinanga*, *S. splendida*, *S. stenoptera*, *S. palembanica* and *S. hemsleyana*.

1.1.Protection by law

Protection of *Engkabang* in general dates back until 1918, when Sir James Brooke prohibited the felling or damaging of Engkabang in a special amendment (Smythies, 1960). Currently, all 6 species discussed in this report; *S. macrophylla*, *S. splendida*, *S. stenoptera*, *S. pinanga*, *S. palembanica* and *S. hemsleyana*, as well as *S. seminis*, are protected by law in Sarawak. They are listed as 'protected plants' under the Sarawak Wildlife Protection Ordinance 1998. In short, collecting or cultivating these species or parts of these species is prohibited, except under and in accordance with the terms and conditions of a license issued under the 1998 Protection Ordinance (Anonymous, 1998). The same rules are issued for the export of these species, where also a license is required. Important to add is the exception that is made, but not stated in the 1998 Protection Ordinance, for the traditional collection of the Illipe nut as product of the Shorea species. The protection rules stated in the 1998 Protection Ordinance are however not applicable for the planted form of Shorea, as in plantations (Lim, Tan, Gan, & Lim, 2011).

1.2.Plantations of Shorea in Sarawak

In 1965, the Government of Sarawak initiated the "Reforestation Research Programme" which aimed at the reforestation of areas damaged by repeated cycles of shifting cultivation. At first, the objective was to test out the fast growing exotic tree species, especially conifers. Poor performance of these species urged the Forestry Department to look for other trees species and from 1970 onwards, tropical hardwood species were selected. Among these species, also *Shorea macrophylla* and later other Illipe nut producing species were included. From the 12.897 hectares planted in Sarawak within the period 1979-1995, about one third (4.780ha) was planted with Shorea species from the Engkabang group. Another 31 hectares was planted with other Shorea species (Krishnapillay, 2002). Apart from planting Shorea for reforestation purpose, there is no record of large scale cultivation of Shorea for commercial purposes in Sarawak (Seng & Hock, 1986). Krishnapillay (2002) mentions the planting of *Shorea spp.* as an additional resource for the rural population of Sarawak, but describes the attitude of the Forestry officials as 'wait and see' when it comes to timber production.

As part of the 1996 Enrichment planting scheme proposed by the Government of Sarawak and executed by the Reforestation Unit of the Forest Department, 10.000 hectares of forest plantation would be established annually. Due to a lack of manpower, in 1998 only 10.000 out of the proposed 160.000 hectares were planted, of which more than 40% is *S. macrophylla* Chai (1998).

In 2011, around 2.8 million ha of state land have been demarcated for plantation purposes, in order to reach the targeted establishment of 1 million hectares of plantation forest in Sarawak by the year 2020. State authorities have set this goal to sustain the timber industry and reducing its current reliance on the natural forests (Lim, Tan, Gan, & Lim, 2011). The total amount of plantation hectares in December 2011 was 289.848, of which 74% consists of *Acacia mangium*, and only 2% of Shorea species from the Engkabang group (Salleh, 2011).

Most of the available data on Shorea originates from studies performed in the Semengoh Forest Reserve (SFR), as most research on these species was performed in this particular area, in the Semengoh Forest Plantation (SFP), although Butt (1982) mentions plantations of Shorea established by the SFD not only in the SFP, but also in Sabal, Sawai, Gunung Gading, the Niah Forest reserves as well as the Oyah Road experimental plantations. In Table 16 in the appendix, an overview is given of all the *Shorea spp.* plantations in Sarawak that were documented in the available literature.

2. Objective

This study will try to prove an additional value other than income generated by timber production on several species of the *Shorea spp.* With the collection of Illipe nuts during the maturing stage of a plantation forest, the revenue can (partly) compensate the establishment and maintenance costs. The main research question and sub-questions of this study are presented below.

What is the production and potential of the Illipe nut in a *Shorea spp*. plantation forest?

I. ***What species of Shorea spp. are used for Illipe nut production in Sarawak?***

II. ***What is the potential yield of Illipe nuts in a Shorea spp. plantation forest?***

III. ***What is the value of 1kg of dried and shelled Illipe nuts?***

IV. ***What is the flowering and fruiting behavior of the Illipe nut producing Shorea species?***

V. ***What are the specifics regarding the production, collection, processing and trade of the Illipe nut in Sarawak?***

2.1. Sequence and structure of the report

This report can be used as a guide to introduce the various aspects of the Illipe nut and its production, collecting and other processes involved. As most of the general aspects of the Illipe nut have been mentioned in earlier literature, this report can be used as a summary of those documents, reflecting and analyzing the important and key factors that are important to know when discussing this remarkable product. Together with the field study performed in the Semengoh forest reserve, which will provide actual data on an existing *Shorea spp.* plantation in Sarawak, a complete picture is given on the potential of the Illipe nut.

The research questions as mentioned in the objective are numbered (I-V) and subsequently discussed in the same order in the methodology as well as the results. In the methodology the collection of the data is explained, including a description of the study area in the Semengoh forest reserve. The results will explain the research questions, and provide the reader with a summary of the relevant data as available in literature.

3. Methodology

3.1.Illipe nut producing *Shorea spp.* in Sarawak (I)

Although there are almost 200 Shorea species present in Borneo and most of them, (if not all) produce nuts, only a small amount bear fruits large enough to be economically viable (Connell, 1968). Apart from the species described in the results, one might find that other Shorea species are actually more productive or suited. The findings of *S. stenoptera* Burck and *S. atrinervosa* furthermore suggests the existence of untapped genetic material in Borneo (Butt & Chiew, 1982). In order to differentiate the Shorea species from each other, determining the best producing and the less important ones, various literature resources were analyzed and compared. Most data was collected from the Forestry library in Kuching, together with some electronic documents. The results of this study have been categorized in an overview of the most important Illipe nut producing species with some information on their appearance. Furthermore, a list is provided with the other Shorea species described as Engkabang and finally a list with all species mentioned as "Illipe nut producing" in the available literature.

3.2.Potential yield of Illipe nuts in a Shorea spp. plantation forest (II)

The potential yield of a certain forest product is best calculated with an example from a real situation. For this study, the inventory in a *Shorea spp.* plantation was needed. An inventory on Shorea species for Illipe nut production has never been performed, and few data is collected on *Shorea spp.* in plantations at all. The collection of field data, such as the number of trees per hectare and their diameter was used in order to provide a realistic image on availability of producing trees in a plantation forest.

Within Sarawak, the choice of suitable areas for a field study on Shorea plantations is easily narrowed down to three sites[1]. In Miri, the Land Development Board maintains four species of Shorea (Sim, 1978) and a relative new experimental plantation in Sabal currently maintains over 2.000 hectares of forest plantations, planted with *Shorea macrophylla* and other *Shorea spp.* (SFD, 2000). Within the Semengoh Forest Reserve, located just 20km. South of Kuching, the Semengoh Forest Plantation is situated. This plantation is not only the first experimental Shorea plantation in Sarawak, but also owns the largest variety in *Shorea spp.* planted in plantation form and was therefore proposed by the SFD to perform this study in.

Because of the long history of research on *Shorea spp.* in this plantation and the best option of finding different Shorea species together in established plantation areas, the SFP was gratefully accepted as the field area for this study. The plantation is situated in the West-Sarawak lowland, in the riverine pan of the Sungai Semengoh. The mean annual rainfall at Semengoh is 4.064mm. per year and the monthly rainfall distribution shows a strong peak during the Northeast monsoon in December and January. Periodical dry periods longer than 30 days are very rare and less common compared to the more coastal regions. The terrain is undulating to low hills with rounded ridges and irregular alluvial flats. The hillocks contain clayish sediment with shale and mudstone (Baillie, 1970). In the flood plain at the entrance of the plantation the soil consists of mottled clay and on the lower hills deeply weathered, moderately deep rooted red-yellow clay-loam. (Sandy clay-loam Ultisol).

[1] The locations from the potential study sites planted with Shorea spp. are given in Figure 18. in the appendix.

The original vegetation predating the plantation is typical Lowland Dipterocarp forest. Because of the traditional shifting cultivation practiced by the indigenous Bidayuh communities the area now has a 70-100 years old secondary forest with an open canopy structure with few larger trees. The dense undergrowth of shrubs, small trees and rattan has an abundant growth of bamboos (Bruenig, 1996). The SFP has since its establishment in 1926 been used to study different species of the Engkabang group. The species *Eusideroxylon zwageri,* commonly better known as 'Belian' or Ironwood, was planted in a single plot and intercropped in one other, but the rest of the plantation consists solemnly of the following species;

FIGURE 2. SECONDARY FOREST IN THE SFP, LOCATED EAST OF PLOT

- *Shorea macrophylla*
- *Shorea pinanga*
- *Shorea splendida*
- *Shorea stenoptera*
- *Shorea palembanica*
- *Shorea hemsleyana*

A total of 15 plots were planted in the period 1926 to 1978, based on the map of the SFP from Sim (1978).[2] Included is one research plot established by the ARC, where several smaller studies have been performed on different Shorea species (Demies, 2013). The map is shown as Figure 15 in the appendix. The establishment of the different plots in the plantation was mainly to observe the growth, flowering and fruiting of the Shorea species in a plantation forest. Other studies included the observation of fruiting under close canopy conditions, the effects of poisoning and seed planting and the effects of compound fertilizer on growth, nut yield and flowering. A broad overview of all the Shorea species planted in the SFP is given in Table 16 in the appendix.

Because of the limited time span available for this study, 8 plots were selected in the SFP, according to their size, age and species. All 6 Shorea species mentioned above are present in one or more plots. Furthermore, these plots were selected because of the availability of data on the performance of the trees, but unfortunately, most of this data was lost during the rehousing of the Forest Research Library. No adjustments on the size or shape of the plots were made. Unfortunately, no coordinates and few maps were available from the location of the plots. In the field, the plots were marked by a sign post at one corner, and wooden poles at each corner. Due to the state of the plantation, the poles were overgrown and moldy, but with the exception of plot 7C, all corners where recognized by these poles. For plot 7C, maps were analyzed and boundaries where established according to tree recognition in the field. Every corner of each plot was then marked by GPS, in order to measure the size of the plot. In all cases, the calculation of the plot sizes matches the original area size.[3] Plot number, size, species and

[2] Based on a received map from the SFD, several more plots were established in the SFP later on, but these are of little importance to this study as they are not included in the inventory (SFD).

[3] Some difference between the original and GPS measured area size occurred due to errors in the exact coordinate determination of the GPS device because of the dense vegetation cover. This error was never more than 3 meters of the actual location.

establishment year is presented in Table 2. Because of its small size (0,11ha), plot 4B (*S. splendida*) will be combined in calculations with plot 9 and 13, both also planted with *S. splendida.*

TABLE 2. PLOT CHARACTERISTICS

Plot number	Area in Hectares	Planted species	Local name	Established in:
4B	0,11	*S. splendida*	Enkabang bintang	1926
4C	2,19	*S. hemsleyana*	Enkabang gading	1935
5C	0,81	*S. pinanga*	Enkabang langgai bukit	1935
7C	1,62	*S. macrophylla*	Engkabang jantung	1936
9	1,34	*S. splendida*	Enkabang bintang	1939
12	0,81	*S. palembanica*	Engkabang asu	1940
13	0,81	*S. splendida*	Enkabang bintang	1940
14	0,97	*S. stenoptera*	Enkabang rusa	1940

3.2.1. Establishment and maintenance

Details of establishment and maintenance of the plots are incomplete and sometimes missing. Available data is collected from a study performed by Tan et al. in 1987 (Tan, Primack, Chai, & Lee, 1987), who compared the growth rate of Shorea in primary forests with the trees in the Semengoh plots.

The planting distance of the plots is 4.5m x 4.5m for plot 5C (*S. pinanga*) and 3.6m x 3.6m for all the other plots except plot 4B, of which no data is available. Since the establishment of the plots in the period 1926-1940, they have been frequently measured and maintained by thinning and clearing of weed species and climber cutting at ground level. Furthermore, competing trees were removed or girdled, with or without poison. All work in the plots was ceased during the war years (1942-45) and all plots were totally neglected during this period. Maintenance in the plots was ceased in 1942 for *S. hemsleyana*, 1950 for *S. pinanga*, 1953 for *S. palembanica, S. stenoptera* and *S. splendida* (plot 13), 1955 for *S. splendida* (plot 4B), 1959 for *S. splendida* (plot 9) and 1960 for *S. macrophylla*.

Because of the long neglect of the maintenance in the plots, undergrowth in all the plots is abundant, most severe in the plots 9 and 13, and least present in plot 4C, where a more forest like structure is present. The diversity of the species present other than *Shorea spp.* was not recorded, but an excellent study covering this topic has been performed by Bruenig in "Conservation and Management of Tropical Rainforests" (1996).

FIGURE 3. ABUNDANT UNDERGROWTH AND CLIMBERS PRESENT. TREE IN THE MIDDLE: *S.STENOPTERA* (PLOT NR. 14)

3.2.2. Sampling and measurements

In the inventory, a nested plot system was used and the guidelines set by the Intergovernmental Panel on Climate Change were applied (IPCC, 2006). For each plot, a full inventory (100%) was done on all trees with a DBH (130cm above ground level) of 30cm and more. From those trees, DBH and tree height (Commercial and Base Crown height) were measured. Furthermore, all Shorea trees were recognized[4] and noted in the inventory. The Shorea trees were furthermore given a quality indication by number 1-4 (1 = Straight stem, 2 = slightly/moderately crooked, 3 = crooked/unusable for timber and 4 = dead standing wood). In order to measure the natural regeneration of *Shorea spp.* and the understory growth of other trees, another inventory, consisting for at least 10% of the size of the original plots was made from all trees with a DBH of >=5-<30cm. In this inventory, tree height (Base crown height) and DBH were measured. *Shorea spp.* was noted in the inventory, but no quality indication was given in this inventory.

For the 100% inventory, rope lines were stretched every 20m distance in the plot using a compass in order to prevent measuring trees twice. For the 10% inventory, squares of 0.04ha (20m x 20m) were randomly placed within the plots. The DBH was measured using a diameter tape and a clinometer was frequently used as verification for the height estimation of the trees. From each plot notes were taken on the natural regeneration of *Shorea spp.* seedlings from last year's crop, which was said to be a moderate one (Chai & Demies, 2013). General info on the state of the trees and vegetation in the plots was also included. All data was collected during a 7 week field study starting in May 2013 on pre-designed field forms and later converted to digital data in Microsoft Excel where it was processed and analyzed.

FIGURE 4. ROPE LINES USED IN THE PLOTS[5].

[4] *Shorea spp.* was easily recognized in the field because of distinctive markings with paint and iron number tags from previous studies and the line planting distribution of the plantation plots.

[5] The white line (starting right) is the main line marking the border of the plot; the blue line is the 1st line in the plot, followed by the red line (near red arrow) which is the 2nd line in the plot at a 20m distance.

3.2.3. Parameters for calculating Illipe nut yields

When calculating the production of Illipe nuts, it is important to take into account the different parameters that influence the yield. Production figures from several literature sources seem to disagree about the production per hectare/tree, but this is most likely the result of the difference in parameters used in each source. For this study, 6 parameters were incorporated in the results and used in the different models to explain the importance and difficulty to predict a certain yield:

1. Crop intensity
2. Different spacing
3. Different forest structure
4. Difference in soil type
5. Differentiation in production per species
6. Tree development (age and diameter)

3.3. Illipe nut values (III)

Before explaining the methodology used in acquiring the value of the Illipe nut per kilogram, it is important to mention that there is no fixed market price for this product, and there has never been one. The price or value has always been depended on several factors, which will be explained in the results. To calculate the value of the Illipe nuts, the available data on the export quantity and values of the Illipe nut in Sarawak where collected from the annual reports of the SFD. Only the export figures of Illipe nuts from the period 1908 until 1998 were found. Figures of more recent years were missing in the annual reports. Furthermore, several documents and literature resources were analyzed in the Forestry Library in Kuching in order to extract all available data on the value of Illipe nuts.

3.4.Flowering behavior of the Illipe nut producing Shorea *spp.* (IV)

Flowering of *Shorea spp.* is typical for the Dipterocarpaceae and happens during irregular intervals of several years in so called mast flowering events. This phenomenon is still relatively unresolved and hard to predict, although extensive studies have been performed. For the production of Illipe nuts, it is important to know and understand when and why the trees will flower and produce seeds. Because of the limited time available and the relative abundance of previous studies regarding this topic, data was collected from various literature resources, some of them present in the Forestry Library of the SFD in Kuching, but most of them by electronic resources. The results mention both the possible explanation of the mast flowering as well as the attempts to influence the flowering behavior of *Shorea spp.*

3.5. Collecting, processing and use of the Illipe nut in Sarawak (V)

In a study on the potential of the Illipe nut, or any non-timber forest product (NTFP) for that matter, it is important to include information about the production, collection and processing of such a crop. For Illipe nuts, information about this aspect of the topic is most well presented in literature. Although the majority of the literature regarding Illipe nuts in Sarawak at least mentions several details about the production and collection of the crop, the studies of J. A. R. Anderson and M. Connell provide a most complete picture on this aspect. In his 'Post harvest study' on the Sarawak Illipe trade, Connell (1968) explains the works involved with the collection and storage of the crop, with numerous recommendations that could upgrade and modernize the current processing. Anderson (1975) provides a broad overview on the different Shorea spp. producing the commercial Illipe nuts and their characteristics. All literature and electronic sources that contributed to the overall picture, or answered some parts of the research question have been included in this report. However, there are too many aspects involved with the production, collecting and processing of the Illipe nut to be mentioned in this report, so only a summary of most topics is included.

4. Results

4.1. Illipe nut producing Shorea *spp.* in Sarawak (I)

Although there are numerous *Shorea spp.* capable of producing Illipe nuts, only a few species produce seeds large enough to be worth collecting. The 6 species that are planted in the Semengoh forest reserve resemble some of the best producers and are presented in Table 3. A more detailed description of the characteristics of tree and nuts is given on page 46 in the appendix, as well as their distribution and soil requirements (Table 15).

TABLE 3. *SHOREA SPP.* PRESENT IN THE SFR.

Vernacular name	*S. macrophylla* (De Vriese) Ashton	*S. splendida* (De Vriese) Ashton	*S. stenoptera* Burck	*S. pinanga* Scheff.	*S. palembanica* Miq.	*S. hemsleyana* (Miq.) King
Local name	Engkabang Jantong	Engkabang Bintang	Engkabang Rusa	Engkabang Langai bukit	Engkabang Asu	Engkabang Gading
Tree size	Tall tree, from 25 to 35 meters	Moderate size	Small to moderate size	Moderate to tall sized tree	Large tree	Moderate to large tree
Timber quality	Light Red Meranti	Light Red Meranti	Light Red Meranti	Light Red Meranti	Light Red Meranti	Dark Red Meranti
Illipe nuts	A very large, good quality nut	Large nut of high repute	Fairly large nut	Medium sized nut	A good, large nut	Large nut, but rarely collected

Although this study will primarily focus on the Engkabang species as present in the SFR (Table 3), it would not be just to ignore 2 species of Shorea, one of which is well known and frequently mentioned in literature as excellent Illipe nut producer (*S. seminis*), or is known to have important characteristics such as an annual producing crop cycle (*S. atrinervosa*).

S. seminis (De Vries) Vansloten is a Shorea species which is often mentioned in literature as a producer of Illipe nuts with excellent quality (Harrisson & Salleh, 1960). The tree can be found throughout Borneo and is frequent and locally abundant at low altitude and clay soils in riparian forest (Anderson, 1975), where it produces a more durable timber (*Balau*) than most Engkabang species. The nut itself is relatively small and often used for local purposes, but has a high fat content of 51.6%.

S. atrinervosa Sym. is particularly interesting because of its ability to produce high yields of Illipe nuts annually (Peters, 2013). Like *S. seminis* also this tree produces the more durable *Balau* timber (Smythies, 1958). *S. atrinervosa* is distributed widely throughout Sumatra and Northern Borneo, Including Sabah, Sarawak and East and West Kalimantan, where it can be found at steep hillsides on clay soils where it is locally abundant. It produces a medium sized nut of 2.5 by 1.5cm. (Peters, 1996).

4.1.1. Engkabang and Illipe nut producing species listed in literature

Commercial Illipe nut producing Shorea species, or Engkabang, are unfortunately not confined to a specified group of species. The name Engkabang is a loose one, and species belonging to this particular group are frequently mixed with other species, mainly because the group members are only defined as 'Illipe nut producing'. Anderson (1975) reports 11 'primary Illipe nut producing' Shorea species belong to this group, with 9 additional Shorea species as 'secondary producers'. Connell (1974) limits the group to 10 Shorea species and Browne (1955) only counts 6 species.

In Table 4, all species listed as 'Engkabang' in the available literature are presented. The 6 Engkabang species from Table 3 are not included. Furthermore, all other species that are known to produce Illipe nuts (of some value), but are not from the Engkabang group are listed in Table 5.

TABLE 4. *SHOREA SPP.* LISTED IN AVAILABLE LITERATURE AS ENGKABANG

Botanical name	Vernacular name	Remarks	Source
***Shorea atrinervosa* Sym.**	Engkabang Tukel	-	(Smythies, 1958)
***Shorea bracteolata* Dyer**	Engkabang Rengit	Probably a misnomer and inferior nut	
***Shorea ferruginea* Dyer**	Engkabang Keli	Believed to be an inferior nut	
***Shorea havilandii* Brandis**	Engkabang Pinang	Mostly on *Kerangas*, little known about the nut	
***Shorea macrantha* Brandis**	Engkabang Bungkus	Large wingless nut, rarely collected due to its local distribution	(Smythies, 1958); (Sim, 1978)
***Shorea mecisopteryx* Ridl.**	Engkabang Larai	Medium sized nut with long wings	
***Shorea pauciflora* King**	Engkabang Cheriak	Probably of little value	
***Shorea seminis* (De Vriese) V. Sl.**	Engkabang Terendak; Tegelam	Not a very large nut, but reputed to be of excellent quality for local consumption.	(Smythies, 1958); (Sim, 1978)
***Shorea smithiana* Sym**	Engkabang Rambai	Nothing known about the nut	(Smythies, 1958)
***Shorea squamata* (Turcz) Benth. et Hook**	Engkabang Layar	Nothing known	
***Shorea beccariana* Burck**	Engkabang Langgai	Medium sized nut, only collected where trees occur in sufficient abundance	(Sim, 1978)
***Shorea amplexicaulis* Ashton**	Engkabang Pinang licin	Nut similar to *S. beccariana*, often occurring in the same habitat	
***Shorea fallax* Meijer**	Engkabang Layar	Medium sized nut	
***Shorea macroptera* Dyer**	Engkabang Melantai	-	(Anderson, 1980)

TABLE 5. LIST OF OTHER ILLIPE NUT PRODUCING *SHOREA SPP.*

Botanical name	Remarks	Source
***Shorea cristata* Brandis**	Small to medium sized nut	(Sim, 1978)
***Shorea parvistipulata* Heim**	Small to medium sized nut	
***Shorea pilosa* Ashton**	Small to medium sized nut	
Shorea scaberrima		(Blicher-Mathiesen, 1994)
Shorea lepidota		
Shorea crassa		
Shorea domatiosa		
Shorea flemmichii		
Shorea parvifolia		
***Shorea aptera* Burck**		(Anonymous, 1915)
***Shorea compressa* Burck**		
***Shorea falcifera* Dyer ex Brandis**		

4.2. Potential yield of Illipe nuts (II)

In order to calculate the potential yield of Illipe nuts in Sarawak, a production figure will be created based on the data collected in the field (Semengoh forest reserve), combined with the data collected in the available literature. This chapter will discuss these results in the following sequence;

- **Parameters used for calculating Illipe nut yields (4.2.1.)**
- **Study area & field results (4.2.2.)**
- **Production figures in literature (4.2.3.)**
- **Models of Illipe nut yield (4.2.4.)**

The **Parameters** presented in this chapter show some important considerations when calculating the yields of Illipe nuts. When these parameters are not (or insufficiently) taken into account of a calculation on the production of Illipe nuts, large differences in yield estimations can occur. The **field results** from the **study area** in the SFR provide the actual example of a *Shorea spp.* plantation in Sarawak at the moment, which will be compared to the **production figures** available in the literature in order to present 3 different **Models** discussing the potential yield of Illipe nuts in Sarawak.

4.2.1. Parameters for calculating Illipe nut yields

Crop intensity

Because of its mast flowering events, yields of *Shorea spp.* cannot be calculated on an average annual production. In general, a distribution can be made in a non-fruiting, moderate or mass fruiting year, but a sequence in these years is missing. However, in order to facilitate a calculation on the yield of Illipe nuts over a period of time, a production cycle of 10 years is created in this report, based on the export figures as shown in Table 10 on page 25. Export quantities were categorized in (A) non-fruiting years, (B) moderate production and (C) mass fruiting years. This 10-year production cycle will be used in each model, although the quantity produced per category (A, B and C) might vary between the models.

TABLE 6. PRODUCTION CATEGORIES BASED ON A 10 YEAR CYCLE.

C	A	C	B	A	B	B	A	B	C
Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10

The distribution of the categories as presented in Table 6 is fictive. This sequence was determined by analyzing the occurrence of as described in the annual reports of the SFD (Smythies, Browne, & Anonymous, 1908-2000).

Different spacing

More widely spaced trees show a much larger Illipe nut production per tree, because individuals are allowed to maintain a much larger crown, enabling a better viability of the tree. Viable trees can produce large quantities of nuts; however, spacing is often neglected in literature. Trees planted for timber purposes usually have a spacing of 3.5 to 4.5m (As in the SFP), although thinned out when trees are mature. A more productive spacing for Illipe nut production would be at a minimal of 10 x 10m planting distance. In the yield models of this study, spacing of the trees will not directly be included as parameter, due to the fact that insufficient data is available on the actual impact of the growth and nut production of the trees. More research is needed to study this influence, in order to find the optimum spacing difference, where a balance is obtained between an optimal timber yield and Illipe nut production.

Different forest structure

Being a forest tree, *Shorea spp.* is able to generate and grow under shaded or understory conditions, but when older, Shorea trees need space for branching, in order to produce substantial yields, as explained on page 18. Yields will be different from trees growing in a primary forest, when compared to trees planted in forest nurseries or plantations. The amount of care, especially in the juvenile stage of the tree is important, such as the removal of competitive trees, climbers and undergrowth. Although all yield models are based on plantation forestry, the level of maintenance (input) is different in each example, whereas model 1. (SFP) can be considered a low input plantation.

Difference in soil type

For optimal yield of Illipe nuts, *Shorea spp.* should be planted in plantations where the soil characteristics of the area at least match the soil requirements of the native stands of the species. Apart from trees that are planted on soil types that do not match these requirements of the species, a deficiency in nutrients can have a large impact on the nut yield. Several studies have been performed on the impact of fertilizers on the growth and fruiting of Shorea species and although a direct link has not yet been proven between fertilizing and flower triggering, the growth can definitely be improved (Lee H. S., 1980); (Sim, 1978). Even in local forest nurseries, the use of fertilizer (chicken dung) for young Shorea trees is a common practice (Harrisson & Salleh, 1960).

Differentiation in production per species

The use of an average yield figure for all Illipe nut producing species is impossible due to the variation in production per species, which is mostly related to the size of the nuts. When analyzing the variation of production figures between the different *Shorea spp.* it seems that not the total production of nuts is the weighing factor, but the size of the nuts, which determines the difference. Although the production per tree in kilograms is very different, the production in quantity of nuts per tree is actually very much the same. It should be noted that different *Shorea spp.,* although mostly synchronized, can have different mast flowering years.

Tree development (age and diameter)

The starting age of Illipe nut production is very different per species of Shorea, and can differ from several years for *S. stenoptera* and *S. pinanga* up to 30 years for *S. hemsleyana*. The age of first flowering furthermore depends on the presence of a mast year at that time and indirect on the diameter of the trees. Several small studies on the (first) flowering of Shorea showed an obvious higher fruiting percentage (and yield) in fruiting trees with larger diameters. (Chin, 1985); (Harrisson & Salleh, 1960). Furthermore, the yield of trees that have just started fruiting is much lower than the yield from trees which are already fully developed.

4.2.2. Study area

The current situation in most of the plots of the SFP can most fittingly be described as forest like. Although the canopy is still dominated by the Shorea species planted, a dense undergrowth of climbers, bamboos and smaller trees has emerged. In the case of *Shorea hemsleyana,* the plantation structure is still the most present, and except for the regrowth of numerous secondary trees, the forest floor is still relatively accessible. On the opposite are the plots planted with *Shorea splendida.* In plot 9 as well as in plot 13, most Shorea trees have died, enabling light to enter the lower stages of the plots which are now completely covered in a dense mass of mainly bamboo clutches. Off all *S. splendida* plots, plot 4B seems to be doing the best, with only a few dead trees and a canopy cover that is still mostly intact. The plots planted with *S. palembanica* and *S. stenoptera* are both performing moderately well. Although understory palms and *Pandanus spp.* are abundant within these plots, most of the canopy is still intact with few gaps.

S. pinanga in plot 5C seems to be doing very well with very few dead trees and almost no competitors in both the canopy layer and the secondary layer. The plantation floor in this plot is covered with shrubs and trees with diameters below 5cm. At the moment of the inventory, the natural regeneration of the last fruiting season was present in massive numbers, but more mature Shorea regrowth was absent. The *S. macrophylla* trees in plot 7C are mostly dying, with few branches bearing leaves and some trees completely rotten, do still standing. The understory of Belian (*Eusideroxylon zwageri*) is very dense and very much alive, with a total of 25 trees (>=30cm) growing an average height of almost 17 meters and an average DBH of 36cm.

TABLE 7. RESULTS OF THE INVENTORY IN THE SFP.

	Nr. of trees * per ha.	% of dead trees	% of unknown trees**	Average DBH*	Average Height*
S. macrophylla	54,3	26,7 %	7,9 %	57,5cm	18,9m
S. splendida	80,5	32,1 %	12,6 %	48,8cm	12,0m
S. pinanga	123,5	4,8 %	8,0 %	47,0cm	19,9m
S. palembanica	67,9	5,2 %	16,4 %	47,8cm	21,0m
S. stenoptera	126,8	11,5 %	18,7 %	43,6cm	15,3m
S. hemsleyana	121,9	16,0 %	12,4 %	45,2cm	20,4m

** Living trees (Shorea spp.)*
*** All secondary regrowth*

It is clear that all the plots, with the exception of *S. hemsleyana,* who still shows no signs of deterioration, are ready for harvesting or are already past this stage. This will undoubtedly also influence the yield of Illipe nuts per hectare, because of the many gaps in the canopy. Because of the fact that most plots are passed their rotation period and the obvious neglect of maintenance, the production figure calculated from these plots will be an example of a low input calculation, as presented in yield model 1 on page 21.

4.2.3. Production figures derived from available literature resources

Below, the various crop yields of some *Shorea spp.* are listed including all available data from the literature resource. Production figures have been divided in production per tree and production per hectare.

Table 8. Production figures per tree.

Species	Dry yield/ tree/year	Comments	Source
Shorea spp.	20kg	Every 3-4 years on average.	(Sellato, 2002)
S. stenoptera	31-63kg	When "fully developed".	(Harrisson & Salleh, 1960)
S. macrophylla	60kg[6]	Trees planted under canopy as forest trees, all flowering for the first time. (1980)	(Chin, 1985)
S. macrophylla	18kg[7]		
S. macrophylla	40kg[8]		
S. macrophylla	240-464kg	Based on a yield table from a combined study of the SFD and the Palm Oil Research Institute of Malaysia.	(Shariff, Amiruddin, & Bujang, Undated)
S. macrophylla	280-400kg	Healthy tree (50-60cm DBH and height >30m).	(Chai E. O., 2013)
Shorea spp.	500-700kg	When "fully developed".	(Ridi, 1998)

Table 9. Production figures per hectare.

Species	Dry yield/ ha/year	Comments	Source
S. stenoptera	133kg	6 years old trees fruiting for the first time (1987) at the Haurbentes plantation, Bogor.	(Suzuki & Gadrinab, 1988-1989)
S. stenoptera	240kg	8-9 years old trees, fruiting every 4-5 years. (yields about 9,000 unprocessed nuts per hectare)	(Menon, 1989)
S. macrophylla	242kg	20 years old trees fruiting for the first time (1955) at Kepong, Peninsular Malaysia.	(Smythies, 1958)
Shorea spp.	293kg	Presented by the Sarawak Gazette, based on the fruiting season of 1973 in the SFP.	(Anonymous, 1977)
S. atrinervosa	440kg	Based on a study in West Kalimantan, which appears to be a yearly production.	(Peters, 1996)
Shorea spp.	1.084kg	Based on the yield of the SFP in 1973.	(Anderson, 1975)
S. macrophylla	1.200-3.480kg	Based on a yield table from a combined study of the SFD and the Palm Oil Research Institute of Malaysia.	(Shariff, Amiruddin, & Bujang, Undated)

[6] Based on 4 trees (age of 21 years).
[7] Based on 1 tree (age of 12 years).
[8] Based on 1 tree (age of 18 years).

4.2.4. Models

Because most of the parameters described in the previous chapter are not known, and the actual impact on the Illipe nut production not yet fully understood, the processing and calculation of a single yield model on the Illipe nut production is not desirable. Therefore, 3 different yield models will be presented in this report, based on the available literature data and field data. Each model will use different parameters that influence the final yield. Model 1 will be fully based on the data collected in the SFP and will therefore be regarded as a "low input model". Model 2 will be based on data analyzed from several literature resources and can be regarded as a "moderate input model" representing average yields from several studies. Model 3 will be based on data that can be regarded as positive at all points. For this model, high yields obtained from several optimistic sources are combined with the production of trees that are planted in plantations with wide spacing and regular maintenance.

Model 1, Low input parameters. (SFP)

Although all models presented in this report are fictive, this model is very accurate and will describe the actual production of the SFP at the moment. All data used in the calculation of this model is acquired from actual sources representing or measured in the SFP. It must be noted that the maintenance has been neglected for a very long time, and that various plot characteristics would be of much better appearance if sufficient attention would have been given to the plantation.

For the mast fruiting years, the calculated yield is based on the production from 1973 as seen in Table 13, and the yield for moderate years is based on the yields of 1979 (Table 17). The amount of trees per hectare represents the actual situation in the SFP, taken from the field inventory of this study. The fruiting sequence is obtained from Table 6. Illipe yields are given per hectare and in dry weight. Because *S. hemsleyana* was not fruiting at the time of collection studies performed in the SFP (as seen in Table 13 and Table 17), the yield figure will be taken from *S. palembanica* which produces nuts of a similar size as *S. hemsleyana.* Because of the age of the plots in the SFP, it is very likely that at least some trees have died in the 10 year prediction of this model. Therefore, a loss of 3.5% per year is calculated for *S. macrophylla* and *S. splendida,* where the highest mortality of the trees was observed and 1% per year for the other Shorea species.

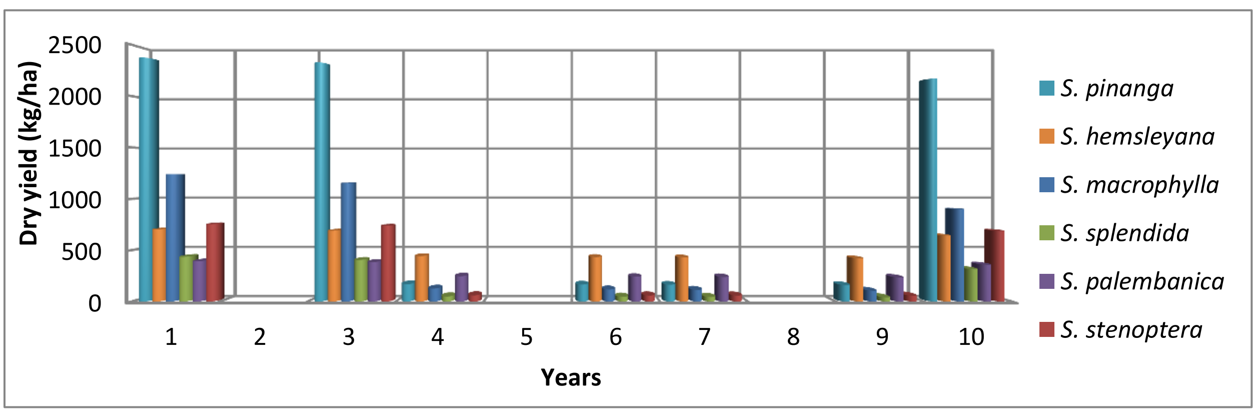


FIGURE 5. PRODUCTION MODEL OF THE SFP OVER A 10-YEAR PERIOD.

As seen in Figure 5 yields of over 2.000kg/ha can be obtained from *S. pinanga* in mast flowering years. Although usually *S. macrophylla* would generate the largest quantity of Illipe nuts because of the large size of the nuts, the low number of healthy trees (55 trees/ha in the first year) in the SFP reduces the production in this figure to around 1.000kg/ha in mast flowering years. The average (dried) Illipe nut production in the SFP (including all species, calculated over a 10 year period) would be **348kg/ha/year**.

Model 2, Moderate input parameters.

Compared to model 1, which was based on the SFP where most parameters were low, this model will present a more average prediction. For this model, a limited number of sources are available and few assumptions have to be made. Therefore, only *S. macrophylla* and *S. stenoptera* will be mentioned separately. The yield is based on yield quantities mentioned by (Harrisson & Salleh, 1960), (Chin, 1985) and (Sellato, 2002) with few adaptions made. The yields per tree are listed in Table 21 in the appendix and the actual yields in a mast fruiting and moderate fruiting year are given in Table 19. A total of 50 healthy and mature trees per hectare are used for this calculation. It must be noted that although this is more favorable for Illipe nut production, a plantation which is originally meant for the production of timber, would have a higher number of trees, reducing the nut yield.

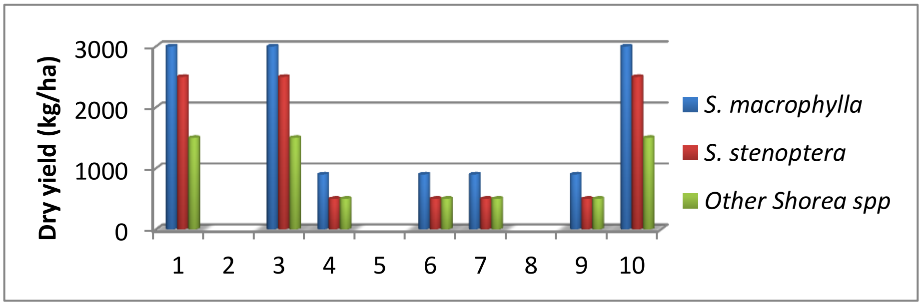


FIGURE 6. PRODUCTION MODEL OF A MODERATE YIELD PREDICTION.

The yield in Figure 6 is based on the same flowering frequency as used in model 1. The dry Illipe nut production of *S. macrophylla* now reaches 3.000kg/ha in a mast year and 900kg/ha in a moderate year. The average (dried) Illipe nut production in model 2 (average of *S. macrophylla, S. stenoptera* and other *Shorea spp.*, calculated over a 10 year period) would be **953kg/ha/year.**

Model 3, Optimal input parameters.

Although in general most studies ((Harrisson & Salleh, 1960); (Chin, 1985); (Sellato, 2002)) mention production figures closer to model 2, some have rather optimistic nut yields, and shall therefore be mentioned in this 3rd model, representing the most optimal possibilities for the Illipe nut production. To give the trees an optimal growing space, the number of trees must be lower than 50 trees/ha, which is no longer profitable for timber production. Although a production as high as 500 to 700kg of dry nuts per tree is mentioned (Ridi, 1998), an optimal yield of 250 to 400kg of dry nuts per tree will produce a yield per hectare exceeding most figures from other literature sources. With just 20 trees per hectare (spacing 25m. x 20m.), one hectare would produce as much as **5 to 8 tonnes of Illipe nuts/ha in a mast year** and the production in moderate years would still yield as much as 1 tonnes of dried Illipe nuts per ha (from 100kg per tree). Using the flowering sequence of Table 6, the average (dried) Illipe nut production in model 3, calculated over a 10 year period) would be **3.200kg/ha/year.** In Figure 7, the yields from model 1, 2 and 3 are combined in one figure, to show the difference in yields per year and overall quantity. The actual data is provided in Table 23 in the appendix.

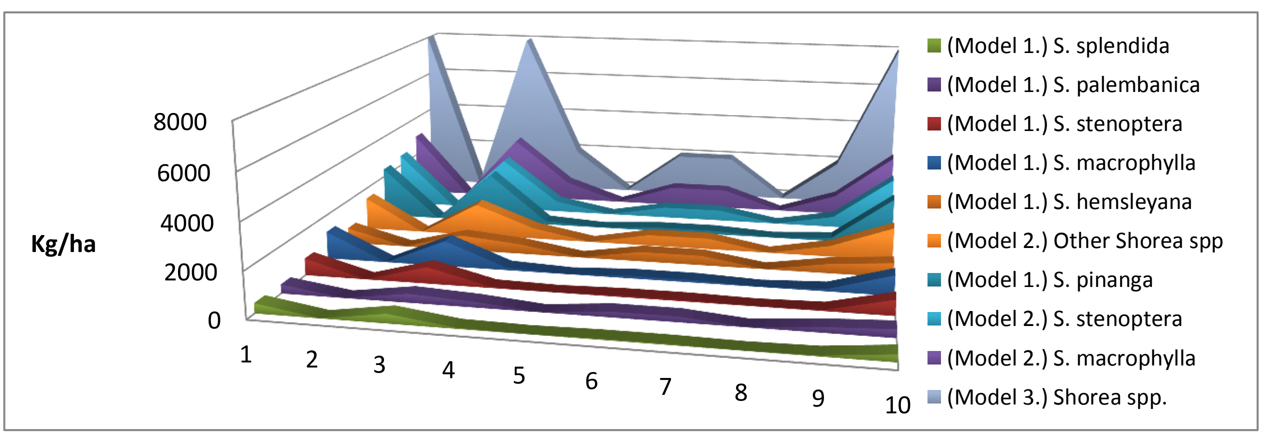


FIGURE 7. PRODUCTION FIGURES OF MODEL 1-3

4.3. Illipe nut values (III)

The trade in forest products, including the Illipe nut, has for long been an important aspect in the establishment of colonies and states in South East Asia. In 19th Century Sarawak, the trade in forest products was an important phase in the commercialization of the indigenous economies and the state authorities derived part of their power from the control on the river traffic and the involved commerce (Kaur, 1998).

4.3.1. Cacao butter equivalent

The export of Illipe nuts has always been linked closely to the chocolate industry and when the price of cacao butter went up in the late 1950's, chocolate producing companies such as Unilever, Nucoline and Cadbury started developing a cocoa butter equivalent (CBE), based primarily on Illipe butter. CBE is a non-cocoa butter created by blending vegetable fats in a precise ratio resembling cocoa butter in both physical and chemical properties (Wong, 1988). Illipe butter is especially suitable for the production of Easter eggs and the high melting point of the fat make it suitable for use in chocolates which are marketed in countries with hot climates (Sim, 1978). Using Illipe butter is cheaper when the price is not more than 65% of cocoa butter (Smythies, 1958). When the price of cocoa butter rose to a very high point at €1.500/tonne in 1970, the commercial production of this CBE boosted the export of the Illipe nuts in the period 1950-1970, exporting more than 5.000 tonnes of Illipe nuts on average per year (but not annually) (Chai E. O., 1998); (Smythies, Browne, & Anonymous, 1908-2000).

For the use in chocolate as a CBE the Illipe butter must be refined. It then varies in color from cream to pale green, possesses a good stability and has a complete melting point of 37°C (Blicher-Mathiesen, 1994). In the sixties, experiments were carried out by the Agricultural Department in Sabah to manufacture Illipe oil named Borneo Tallow. The product was sold in the United Kingdom for some extent but was there regarded as inferior compared to the oil extracted from imported nuts. Because of the expensive machinery involved and the sporadic nature of the crop, extraction of the oil in Malaysia was considered uneconomical (Harrisson & Salleh, 1960).

4.3.2. Price fluctuation

During a mass fruiting season, prices offered by buyers fluctuate following a pattern that is mainly based on the availability of the crop. Although the initial market price is dictated by the current price of cacao (Anonymous, 1977), a drop is seen when supplies saturate the market (Chin, 1985). At the end of a season, when the final crop reaches the market, prices usually go up again, as can be seen in Figure 8. After processing, the shelled and dried nuts are sold to (mostly) Chinese middlemen.

Prices, although said to be artificially manipulated by 'up-river' traders, are sustained for several reasons. First, collectors bringing their yields down the river to be sold are unlikely to be bringing their goods back because of a low price at that time. Furthermore, the fast deterioration of the nuts prevents them to simply wait until prices go up again, because inferior nuts will be worth even less (Chin, 1985). On the other hand, traders cannot offer a price below a certain 'incentive price limit' because collectors would lose interest in collecting the crop at all (Connell, 1968). This limit is related to the prices offered for rubber at that time, together with the costs of rice and other factors. Furthermore, the values offered for Illipe nuts are dictated by the current value of cacao. Cocoa prices set a very clear ceiling to the Illipe prices, and it can be seen that when cocoa prices drop, the prices offered for Illipe nuts will also go down. Even when prices drop below the 'incentive price limit' the earnings would still provide a valuable income for the country.

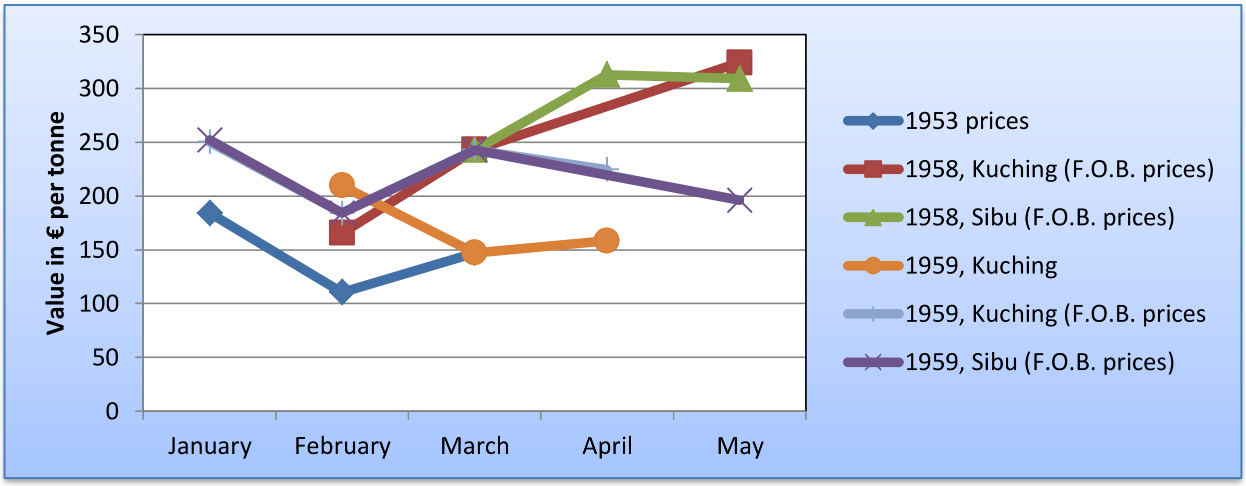


Figure 8. Price fluctuations in Illipe nut prices during harvesting seasons (Harrisson & Salleh, 1960).

Export dates back as early as 1856, when 652 tonnes of Illipe nuts were exported from Sarawak. The next registered shipment was in 1903, exporting 710 tonnes (Blicher-Mathiesen, 1994). Yearly export figures are available from 1908 until 1998 and are listed in Table 10 on page 25. Years with no export and the period of 1941-1945 (Japanese occupation of Sarawak) are not shown in this table. The absence of data from 1999 and onwards should be noted, because export values from this period would provide this study with an accurate prediction of the expected revenue at this time. Apart from fluctuations within a fruiting season as can be seen in Figure 8, fluctuations are also visible in the export values over the years, as can be seen in Figure 9.

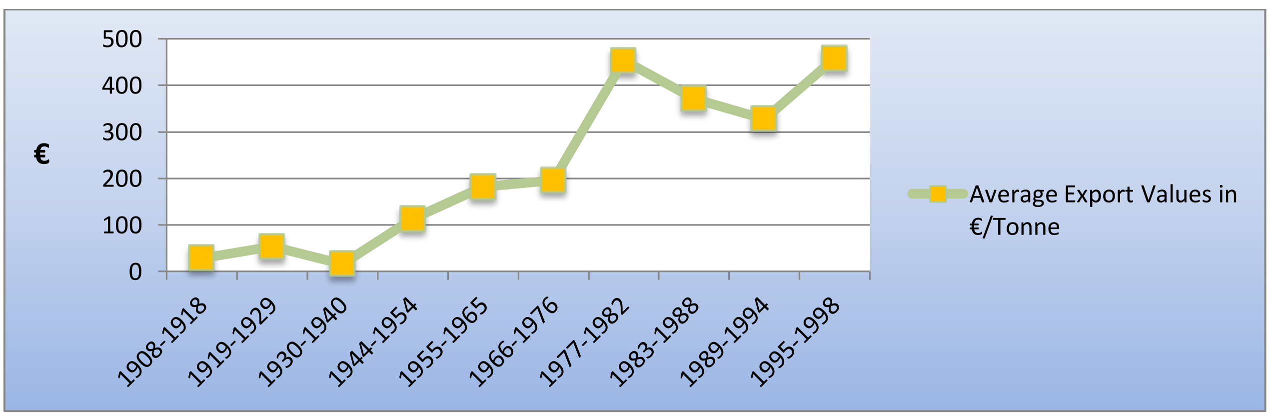


Figure 9. Average export values of the 20th century (Smythies, Browne, & Anonymous, 1908-2000).

Export quantity and value of Illipe nuts (1908-1998)

Table 10. Export quantity and values of the Sarawak Illipe nut.

Year	Export in Tonnes	Value in € per Tonne
1908	2.339	€ 21,78
1909	248	€ 21,96
1910	52	€ 24,00
1911	285	€ 30,65
1912	3.627	€ 28,81
1913	1	€ 30,85
1914	2.696	€ 39,20
1915	3.206	€ 34,96
1916	6	€ 17,76
1918	6	€ 16,09
1919	6.747	€ 53,21
1920	1.055	€ 69,17
1922	15	€ 34,32
1923	15.060	€ 39,60
1924	369	€ 25,64
1926	363	€ 92,80
1927	6	€ 59,30
1928	883	€ 59,45
1929	7.476	€ 46,21
1930	118	€ 28,27
1931	6.188	€ 9,00
1932	98	€ 7,59
1934	9	€ 16,87
1935	4.981	€ 14,25
1936	182	€ 10,23
1937	6	€ 31,93
1938	16	€ 17,77
1939	31	€ 17,85
1940	480	€ 6,39
1947	7.658	€ 54,99
1948	22	€ 51,06
1949	752	€ 131,34
1951	22	€ 93,55
1952	30	€ 114,42
1953	2807	€ 169,37
1954	16.047	€ 174,72
1955	1.452	€ 133,48
1956	158	€ 129,52
1958	6.205	€ 254,68
1959	22.006	€ 201,40
1961	15	€ 208,66
1962	19.883	€ 178,74
1965	502	€ 164,39
1966	6.761	€ 151,19
1968	15.774	€ 179,68
1970	16.554	€ 231,48
1973	28.061	€ 159,46
1975	8	€ 230,37
1976	50	€ 222,85
1977	4.820	€ 575,33
1978	94	€ 317,96
1979	429	€ 556,72
1980	11.105	€ 557,84
1981	1.619	€ 403,22
1982	22.950	€ 308,34
1983	1.476	€ 248,96
1985	144	€ 503,76
1986	8.443	€ 524,19
1987	23.444	€ 330,22
1988	1.042	€ 248,98
1990	13.036	€ 367,26
1991	5.839	€ 388,34
1992	464	€ 243,06
1993	5.390	€ 285,50
1994	562	€ 355,68
1995	14.242	€ 316,10
1997	101	€ 399,97
1998	3.329	€ 656,88

Source: (Blicher-Mathiesen, 1994); (Connell, 1968); (Smythies, Browne, & Anonymous, 1908-2000); (Tan, Primack, Chai, & Lee, 1987).

4.4. Flowering and fruiting behavior of *Shorea spp.* (IV)

The flowers of each species of Shorea are small (roughly 1-1.5 cm in length), cream-colored and bell-shaped. Flower buds are present 2 weeks before flowering. Flowers open at dusk, spreading a penetrating, sickening sweet smell with more than a million blossoms present on a single tree per night at its peak bloom. The corollas drop to the forest floor the next day. Flowering ranges roughly from 2 to 3.5 week, spread over an 11 week period flowering season.

Shorea are almost solemnly pollinated by thrips (Thysanoptera), with 2 species of the genus Thrips and one of the Lemuro-thrips accounting for over 95% of the floral visitors. Because the generation time of 8 days and high fertility (27 eggs per female), Thrips are the ideal pollinators for mast fruiting species as they can rapidly increase their numbers during such an event. In between mast fruiting events, Thrips sustain in low numbers, while feeding on continuously flowering trees of several understory species such as *Randia scortechinii* King (Ashton, Givnish, & Appanah, 1988).

4.4.1. Mast fruiting

The mast fruiting of Dipterocarpaceae, also called “gregarious” or “general” fruiting, is a behavior very similar to the fruiting of some North American and European families, such as Fagus and Quercus. The Dipterocarp flowering and fruiting events in the aseasonal tropics of Borneo show sporadic flowering occurring every year, with large mast flowering happening at intervals of 3 to 4 years and sometimes even 5 to 10 years (Ashton, 1988). At these irregular intervals several species of Dipterocarps, as well as some other canopy members, such as the, Fabaceae, Myristicaceae, Polygalaceae, and Sapotaceae, come into flower more or less simultaneously. Over a period of some weeks to a few months nearly all Dipterocarps and up to 88% of all canopy species can flower after years of little or no reproductive activity (Medway, 1972). The region over which such a mass-flowering event occurs can be as small as a single river valley or as large as Northeastern Borneo or Peninsular Malaysia. Although these mast flowering events usually occur synchronous within populations and within several months, Shorea does not always follow this timing, making it very hard to predict when or where a mast fruiting event will occur (Appanah S. , 1993).

Janzen (1974); (1971) as well as Ashton (1988) describes the mast fruiting displayed by the Dipterocarpaceae, as a mechanism of escape from seed predators. The advantage of this highly synchronized event is to saturate the seed predators and increase the amount of seeds left untouched. The event is unique to the South-east Asian part of the tropics because of the reduced animal communities and the availability of a sufficiently uniform climate. These ingredients stimulated the evolution of such a striking event. In Borneo, it is well known that many Dipterocarp genera fruit synchronously over large areas, of which *Shorea spp.* is probably the best known (Ashton, 1964).

Many studies explain the phenomenon of mast fruiting, including the characteristics, length and tree families involved. However, the actual triggering factor(s) seems to be not yet fully understood. Several environmental events have been proposed as floral triggers for mass flowering in Dipterocarps, including prolonged drought (Boswell, 1940); (Janzen D. H., 1974), increased number of cloudless hours of direct sunlight (Wycherley, 1973) and a drop or rise in mean temperature (Wycherley, 1973); (Appanah S. , 1985).

Janzen (1974) gives an excellent hypothesis, explaining that the event probably involves little more than the storage of photosynthate, until the amount is needed to produce a seed crop of a size that accomplishes seed predator saturation. Once this level is reached, the tree becomes physiologically sensitive to an external weather event that will be likewise perceived by other Dipterocarps. This weather event appears to be a period of 2 or more rainless weeks in the case of Sarawak and Brunei (Chai & Demies, 2013) (Ashton, 1964).

Appanah and Ashton (1988) studied the possible triggers for a mast fruiting event, and presented that a drop in the minimum nighttime temperatures of at least 5 to 8 days could be associated with each flowering event, as it preceded the event 8 to 9 weeks. They argued that a drop of only 2°C in minimum temperature for several nights might be sufficient to induce flowering.

It is possible that several factors at one time are needed to stimulate the flowering and more research is needed to accomplish full understanding on the exact processes involved in the triggering of a mast fruiting event.

The fruiting sequence of the Shorea species is a splendid example of the mast fruiting observed within the Dipterocarpaceae. Fruiting can occur every 3 to 4 years (Anderson, 1975), with sometimes intervals of 5 years in between a mass fruiting event (Connell, 1968). Although some records of flowering are known, no accurate register of fruiting events and their intensity is available. Fruiting can often be categorized in a non-flowering year, medium and mass fruiting event, but does not show a clear sequence, and is very hard to predict. An example of the irregularity in the *Shorea spp*. fruiting occurrence can be found in Figure 10 which is based on the export quantity of Illipe nuts in Sarawak. The gap present between the years 1941 and 1945 is due to Japanese occupation of Sarawak during World War 2, as no records were taken during this period (Harrisson & Salleh, 1960). At least 2 flowering events have occurred during the occupation, but numbers or intensity of the crop is not known (Smythies, Browne, & Anonymous, 1908-2000). Although *Shorea spp.* generally flower and fruit at the same time and period, the intensity of the crop depends on the species itself.

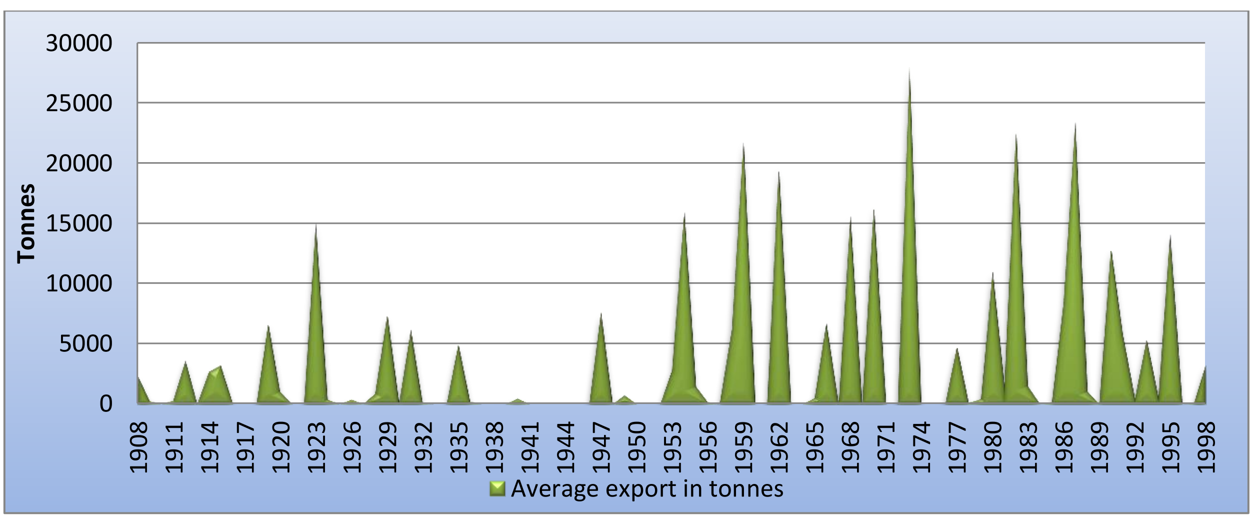


Figure 10. Fruiting events based on export of Illipe nuts from Sarawak.
Source: (Connell, 1968)*;* (Smythies, Browne, & Anonymous, 1908-2000)*968);* (Tan, Primack, Chai, & Lee, 1987).

4.4.2. Flowering induction

As the irregular flowering pattern of Shorea can be seen as a major obstacle in the attempts to commercialize the Illipe nut trade, several studies have been performed to study the possibility of influencing the flowering patterns of the Shorea species. In this chapter the possibilities and results of these studies will be discussed.

In the SFP, a trial plot was planted in 1962 to study the effect of fertilizer on the growth, nut yield and flowering of *S. macrophylla* and *S. pinanga* in a 12.96ha plot. Although the trees flowered and fruited after 6 year (Lee H. S., 1980), no significant difference was obtained between the fertilized and non-fertilized trees. However, the growth rate of both species was significantly increased with both species, with the greatest response from *S. macrophylla* (Chiew & Yaw, Unknown).

In 1973, the State Government of Sarawak introduced the domestication of Illipe nuts as one of its directives. To achieve this goal, the possibility of regular fruiting needed to be investigated. In 1976, a fertilizer treatment was given to *S. macrophylla* trees of 1, 7 and 12 year old to determine possible flowering induction in the following fruiting season, but no flowering was observed. 3 other studies were performed, including a sprayed fertilizer and fertilizer injection on young plants of *S. macrophylla*, *S. stenoptera* and *S. pinanga*. One experiment added growth regulators to trees of *S. macrophylla*, but none of the studies showed obvious change in growth pattern or flowering (Sim, 1978).

Although several new plots were planted in the SFP in 1970, 1975 and 1977, including the species *S. macrophylla*, *S. stenoptera*, *S. splendida* and *S. hemsleyana*, most of the maintenance and observation in this plantation was seized after 1980 (Chai E. O., 2013), so no data is available from these plots.

It seems that this major obstacle in the production, which hinders the continuous export of the Illipe nut, is not solved by a variety of fertilizer treatments and solutions must be sought in different directions. The existence of an annual producing species, such as the *S. stenoptera* Burck and *S. atrinervosa* (Anderson, 1975); (Peters, 1996), would solve this problem.

4.5. Collecting, processing and use of the Illipe nut in Sarawak (V)

As Illipe nuts are obtained from several species of Shorea, various sizes and shapes occur. Mostly, the nuts are egg shaped, with wings as is characteristic for the Dipterocarpaceae. These wings vary in size and can be larger or smaller than the nut itself. (Anonymous, 1915). The largest Illipe nut is Shorea macrophylla (Figure 11) and the smallest Illipe nut is *Shorea seminis* (Figure 12). Both species are used in the Illipe nut production, where *S. macrophylla* is the most important producer of Illipe nuts and *S. seminis* is well sought for its good tasting qualities.

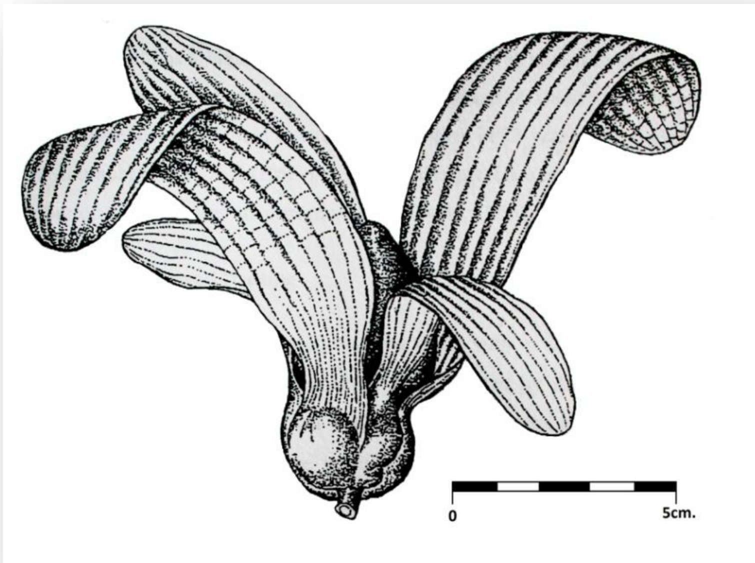


FIGURE 11. ILLIPE NUT, *S. MACROPHYLLA*. ACTUAL SIZE ON SCALE (CONNELL, 1968)

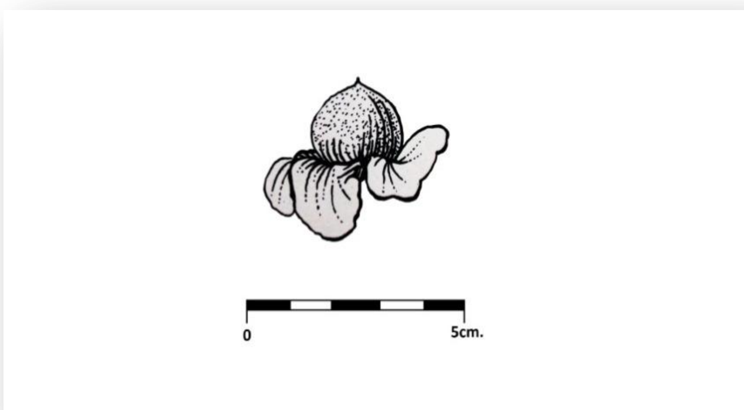


FIGURE 12. ILLIPE NUT, *S. SEMINIS*. ACTUAL SIZE ON SCALE (MEIJER & WOOD, 1964)

4.5.1. Illipe nut production

Although flowering and fruiting of the described species occurs generally in September to October followed by the fruiting in January and February, extending to March and April in some years (Chai E. O., 1998), the production, size and other characteristics of the Illipe nuts are quite different.

Crop yield of Illipe nuts can be presented in the production per tree or per hectare. All figures presented will be given in kilogram and the yield represents the de-winged and dry nuts. Although there is a large variety in the production figures, a yield of 20 to more than 60kg seems to be the prevailing value of nuts per tree, although yields as high as 500 to 700kg are recorded. Crop yields per hectare average on 250kg with values of 1.000 to 3.000 kilograms recorded. All production figures derived from the available literature are listed on page 45.

Chin (1985) performed a rare study on the yield of *S. macrophylla* related to its diameter in 1980. This was a moderate fruiting year and the income generated for this village was just a fraction of the usual cash flow generated by a bumper crop, meaning that production figures would probably be higher if the study was performed in a bumper fruiting season. All trees were 18 years old and fruiting for the first time. Trees were planted at 4.5 to 9 meter spacing. In Table 11, the results from this study show the clear increase in production when the trees reach a diameter of 40 cm. The study shows a clear distinction in the yield of younger and fully mature trees and why it is important to keep the age and diameter of the tree in mind when calculating the production figures, as it has a major influence on the intensity of the crop.

Table 11. Yield figures related to diameter (*S. macrophylla*)

Diameter	No fruits	< 2Kg.	2-10 Kg.	>10 Kg.
10	2			
12	2			
20	1			
23	1			
25	1			
26	1			
27	2			
28	4			
29	1			
30	6			
31	1			
34	3			
35	5	1		
36	2			
37	4			
38	1			
40	1	1		
41	3		1	1
42	1	1		1
43	1			
46			1	1
51			1	
53				2
55				1
56				1
57				2
60				1
62				1
68				1

Possibly the most suitable study performed on the production figures of Illipe nuts from various Shorea species was performed in the SFP by the SFD. These figures (Table 12 and Table 13) were used in various literature sources and will also be used as reference in this study, combined with the field results from the same plantation. Most data from Table 13 was collected from the Semengoh plantation in 1973, which was an exceedingly good year, a so called bumper fruiting crop. It must be noted that there was an extremely heavy fruiting of *S. pinanga*. In the same study, the production of Illipe nuts per tree was calculated. Unfortunately, data on *S. hemsleyana* was not included in these results because it was not flowering at that time (it was flowering in 1974, but collection figures from this year are missing (SFD, 1974 & 1977)). Following the fruiting events in 1976 and 1977, the crop from 1979 appeared to be a moderate one. Yield figures from this year are presented in Table 17 in the appendix. No further data on the yield of Illipe nuts in the SFP or other areas is available in literature.

TABLE 12. ILLIPE NUT SPECIFICS.

Species	Shape of the nut	Avg. Fresh weight per nut	Dry yield per Hectare	Fat %	Avg. Dry weight per nut	1st Flowering age (years)
S. macrophylla	Obovoid	51,1g	1.762kg	51%	20,10g	15
S. splendida	Ovoid	23,2g	618kg	49%	10,69g	29
S. stenoptera	Ovoid	37,7g	808kg	48%	7,66g	30
S. pinanga	Ovoid	19,0g	2.280kg	49%	9,32g	6
S. palembanica	Conical	5,9g	618kg	37%	3,92g	29
S. hemsleyana	Ovoid	4,5g	-	-	-	38
Source: **(Iqbal & Sim, 1973)*;* (Smythies, 1958)*;* (Blicher-Mathiesen, 1994)*;* (Anderson, 1975)*;* (Chin, 1985)*;* (Sim, 1978).**						

TABLE 13. ILLIPE NUT YIELD IN SFP IN 1973 (ANDERSON, 1975).

Plot nr.	Species	Area in hectares	No. Of trees	No. Of fruits collected	Avg. No. Of fruit/tree	Total dry weight	Avg. Yield/ tree
7	***S. macrophylla***	1,62	125	142.006	1,136	2.854kg	22,83kg
9,4B,13	***S. splendida***	2,26	259	130.686	505	1.397kg	5,40kg
5C	***S. pinanga***	0,81	96	198.160	2.064	1.847kg	19,24kg
12	***S. palembanica***	0,81	35	33.408	955	131kg	3,74kg
14	***S. stenoptera***	0,97	132	102.328	775	784kg	5,94kg

4.5.2. Collection of the Illipe nut

In Sarawak, Illipe nuts are essentially a wild crop (Smythies, 1958) and the nuts are traditionally harvested as a forest produce, but have a large commercial impact and even bigger potential for everybody involved in the collecting, processing and trade (Noorzita, 1987). However, some cultivation occurs, as trees are planted close to longhouses of the indigenous people (Chin, 1985). In West Kalimantan, a large percentage of the collected nuts come from cultivated or deliberately managed trees, a practice that has been going on for several hundred years (Peters, 1996). A more detailed review of the traditional collection of the Illipe nut is given in annex XIV on page 59.

The most active collectors of the Illipe nut are the Sea Dayaks, Land Dayaks and Kayan people (Connell, 1974). During a harvesting event, one family may collect and process as much as 600kg of dried Illipe nuts (Anonymous, 1977). In general, the collected quantity of a crop may depend on three main factors; (1) Availability of fruiting trees, (2) availability of labor in order to collect and process the nuts and (3) the efficiency of transportation and communication between collection areas, collectors residences and export centers (Connell, 1968).

In order to obtain the best quality, nuts should be collected as soon as they fall from the tree (Smythies, 1958), because germination is rapid, usually 2 to 3 days, and the oil content of the nuts is much lower for germinated or developing nuts. While fresh nuts contain fat percentages up to 50%, germinated or infested nuts have been sampled with a fat content of 8.7% and even 4.1% for more mature seedlings (Connell, 1974). Collection from the trees is discouraged and forcing the nuts to drop by lighting fires underneath fruiting trees is prohibited (Sim, 1978).

The major collection area within Sarawak lies within the 3rd Division[9], now the Sibu district, however collection in the Kuching district and in the central parts of Sarawak is also substantial (Connell, 1968). An example of the collection (in export quantities) over the period 1954-1959 is given in Table 14, divided by the Divisions of Sarawak. The table shows clearly where collection is most heavy.

Table 14. Illipe export by Division. (Harrisson & Salleh, 1960)

	1954	1955	1956	1957	1958	1959	% of total
1st and 2nd Division	340.053 kg	3.583.925 kg	8.373 kg	0 kg	28.591 kg	582.019 kg	**71,5 %**
3rd Division	606.324 kg	22.771 kg	1.183 kg	0 kg	345.733 kg	805.682 kg	**28,0 %**
4th Division	24.003 kg	1.513 kg	0 kg	0 kg	0 kg	0 kg	**0,4 %**
5th Division	117 kg	4.222 kg	0 kg	0 kg	0 kg	0 kg	**0,1 %**

Collecting rights

When it comes to the collection of the Illipe nuts, the laws can be little confusing. In fact, all Engkabang trees, and their nuts, are government property, unless the trees are actually planted by somebody. (Connell, 1968). Some trees are owned by indigenous people as they are either planted by their ancestors or by themselves. Therefore, some "wild" trees are in fact not totally wild when the community abandoned their village or longhouse and migrated to a new settlement, as is common in the shifting agriculture they practice (Ridi, 1998). Indigenous people have the right to collect these nuts at a primary level and trees that are within easy reach of a longhouse belong traditionally to this community. Additional rules are sometimes applied; outsiders are only allowed to collect nuts floating down the river, and sometimes outside collectors are prevented to enter a certain area by the longhouses. In some cases disputes arise between longhouses about the ownership of a certain collection area, but most of the time, when the nuts start to fall, people are too busy collecting and leave the quarrels for what they are (Connell, 1968). The collection of Illipe nuts in forest reserves is not allowed but often neglected by people entering these areas illegally (Shariff, Amiruddin, & Bujang, Undated).

4.5.3. Illipe nut processing

The processing of the Illipe nut can in general be divided into two main methods, producing two different products, in the trade recognized as "black" and "brown" nuts. After collection in the field, the fruits are taken to the village or a temporary shelter at the end of the working day to be processed afterwards (Chin, 1985). In areas where fruiting is heavy and competition for the harvest is high, the temporary storage of unprocessed nuts can remain undisturbed for as long as 8 weeks (Connell, 1968). When collection is finished, the nuts are stripped of their wings using a blunt instrument or stick, by striking at the base of the fruit (Anderson, 1975). The black nuts are obtained from a method which includes submerging the nuts under water and then dried, while the brown nuts are obtained from immediate drying of the nuts, usually above a small fire. The complete process including several versions of this process is presented in Annex XVI on page 61.

As described on page 31, the processing must be done as soon as possible, in order to prevent the nuts from germinating or becoming infected by insects and other micro-organisms. The processing involves the removal of the wings, the sorting of deteriorated nuts and already germinated specimens. Then the germination process must be stopped, which is most practically done by heating the nuts until dry.

[9] A division map of Sarawak is included on page 65 in the Appendix.

4.5.4. Illipe nut storage

In order to avoid deterioration of the nuts, it is necessary that the moisture content of the product and the relative humidity of the environment are not too high (Okwelogu, 1969). Connell (1968) urges the necessity to dry the nuts to moisture contents of below 7% in his report on the Illipe nut trade of Sarawak, as this prevents deterioration of the stored products. Insect pests, attracted by the large quantity of an Illipe yield, do substantial damage and expose the nuts to infection of micro-organisms, which cause a depletion of the fat percentage. Poor communication between the end users and the collectors, fed by the uncertainty of a crop, the complexity of the trading arrangements and difficulty to reach the collectors are the main reasons for the lack of improvement on the hygiene and quality of the product that is delivered.

Although collectors put a considerable amount of time and labor in the gathering, transporting, shelling and drying of the nuts, the traditional methods of sun drying or kiln drying as performed by the collectors will only reach moisture contents of 10-12%, which is not sufficient to prevent further deterioration of the nuts (Connell, 1974). A full and excellent study on the problems involved with the storage of Illipe nuts is done by Connell in 1968, who studied not only the pests involved, but also established guidelines and provisions that would greatly increase the quality of the crop. The primary recommendations involved the storage of Illipe nuts below a moisture content of 7% and the fast collection and processing of the nuts, in order to prevent germination.

4.5.5. Use of the Illipe nut

Because of its high oil content, Illipe nuts have been in high demand on local and foreign markets. The fat, known as Borneo Tallow, Illipe Butter, or locally as Minyak Engkabang is used for edible purposes by the local inhabitants of Borneo, where the oil is used locally primarily as a flavoring with rice (Anonymous, 1977); (Harrisson & Salleh, 1960). Exported nuts, shipped primarily to the European countries, are used in the manufacturing of candles and similar purposes, although the prime value lays in the similarity of the Illipe butter with cocoa butter, for which it is used as an alternative (Anonymous, 1915).

The fat of the Illipe nuts is described as a tallow-like substance, yellowish or greenish, depending on the species it is derived from. It consists mainly of glyceride, with a fatty acid composition of Stearic acid (41%), Oleic acid (38%) and Palmitic acid (21%) (Blicher-Mathiesen, 1994). As the nuts are merely selected for export by size and sometimes color, the fat content can vary (Browne, 1955). Other than collection of the nut by people, Illipe nuts are also an important source of food for the forest wildlife, of which insects, small deer and wild boars are probably the best example (Chai E. O., 1998). Migrations of pigs (*Sus barbatus*) in search of Illipe nuts during mast fruiting seasons are famous in Borneo (Whitmore, 1975).

Fat content of examined Illipe nuts differs from species to species and even between individual nuts (Blicher-Mathiesen, 1994). Average fat content studies show a content as high as (52%) for *S. macrophylla* (Okwelogu, 1969) and 60% for *S. seminis* (Blicher-Mathiesen, 1994) and as low as 41% by other species from the Engkabang group (Smythies, 1958).

Local use

An Illipe nut harvest is not solemnly welcomed because of the cash flow that it generates, but also for the variation in food that it supplies. With a menu of rice with dried fish and some flavoring, Illipe nuts give the menu of the indigenous people of Sarawak a most welcome upgrade. Harrisson (1960) mentions at least 7 recipes, where the nuts or their oil are used purely or mixed with other ingredients such as Durian (*tempoyak*) or Prawn paste (*belachan*) in the daily meals. An overview of some documented recipes is given on page 57 in the appendix, but the local variety and uses of Illipe nuts in food are probably countless. Locals do have preference for certain species when it comes to taste. *S. hemsleyana* is said to produce a nut with a slightly bitter taste while *S. seminis* has a pleasant taste and good lasting qualities (Browne, 1955).

There are several ways to extract the oil from the nuts, but the most traditional way to make "*Minyak Engkabang*" is to crush the dried cotyledons in a rice pounder and boil the pounded mass in water. The fat then surfaces and can be skimmed off, strained and left to harden out in small bamboo stems. Usually the smaller nuts are used for home consumption while the bigger ones are exported (Chai E. O., 1998). The cake remaining after the extraction of the fat from the nuts is marketed as "Illipe cake" and used for feeding livestock (Anonymous, 1915). However, on account of the low protein content of 10.9%, other sources such as linseed and groundnut meal are preferred (Smythies, 1958).

Export purposes

The marketed "nuts" consists only of the kernel, which comprises the two large cotyledons without the wings or the shell (Anderson, 1975). The principal foreign markets are in the U.K., the Netherlands and Japan, where the oil is mainly used in the confectionary industry and especially in the manufacture of chocolate, as a cocoa butter alternative. The oil is also marketed in the soap manufacture, cosmetic industry and to a small extends for medicinal purposes (Anonymous, 1977), but the quantity used for these purposes are insignificant compared to the quantity used for chocolates (Smythies, 1958).

5. Discussion

The results presented in this report are collected from various literature studies as well as from data collected during a 3 month period in the Semengoh forest plantation. Because of an extensive study on the available literature on the Sarawak Illipe nut, this report does not only contain the findings of this particular research, but also the opinion and summarized findings of previous studies on the subject. This provided the opportunity to compare results and analyze differences between them. The most distinctive differences in literature were found in the prediction of the Illipe nut production per tree or per hectare.

Regardless of extensive research on available data of current values of Illipe nuts, literature dating from 1999 and onwards was not found. Therefore, a prediction of the current value of Illipe nuts in Sarawak is not presented in this report. However, an overview of the value of the Illipe nut in history has been provided in chapter 4 on page 14.

The production of the Illipe nut in a Shorea plantation forest depends on a various amount of aspects, each more or less influencing the yield. The most obvious of these parameters are given in this report, although it is very likely that there are some additional influences which are not mentioned. The great difficulty in the calculation of a potential Illipe nut yield lies in these parameters and in what way they may, or may not influence the yield of a certain plantation in a particular area. The aspect of the parameters and their particular influence is given extra attention, because if they are understood and studied, only then a true prediction can be given on the yield of the Sarawak Illipe nut. Furthermore, instead of acceptance of the (negative) influence of the parameters, solutions should be sought in editing the parameters in such a way that their influence becomes irrelevant or even positive.

There is a great need for research on the in this study presented parameters, proving to what extend each of them influences the yields in what way and with that information, a true model can be constructed on the potential yield of Illipe nuts in Sarawak, that can predict yields according to for example; type of species, soil or number of trees per hectare. One of these parameters, on which this research was unable to study the characteristics, is the use of an ideal spacing of trees in a plantation. Illipe nut production is directly influenced by the crown space trees are allowed to obtain in a plantation, although to what extend is not known. In order to favor timber and nut yields, an ideal spacing should be used that allows trees to produce a vital crown, providing a better yield of Illipe nuts, but also has enough trees per hectare to be economically viable as a timber plantation.

Annual production

Another parameter which influences the production of Illipe nuts is the irregular mast flowering of the Shorea family, resulting in an unpredictable yield cycle with minor yields in 35% of the years and bumper crops in other years (Panayotou & Ashton, 1992). These large differences in yields seem to have prevented the Illipe nut to maintain the major export product as it once was, because of the lack of a stable supply. Although several studies, as described by Sim (1978) have tried to find the answer to this problem by fertilizer treatments triggering the flowering of Shorea, no statistical differences were recorded, although some differences in flowering patterns were recognized by Lee (1980). Peters (2008) described the existence of an annual producing type of *Shorea atrinervosa,* in West Kalimantan, producing 440kg of dry Illipe nuts per hectare, which would at least tackle the problem of the irregular flowering. Suzuki (1988-1989) and Sim (1978) both mention some type of *Shorea stenoptera* to produce annually, even do yields fluctuate over the years.

Field study

Concerning the SFP, the overall health of the trees is currently poor, resulting in a low number of trees per hectare and subsequently production of these trees. Several plots where in such a decrepit stage that a viable production is questionable. It is important to note that with some increased management efforts in the past, the current production of the plantation would be much higher. Furthermore, the age of most of the Shorea species in the SFP is currently exceeding that of a vital plantation, resulting in yields that are already past their maximum capacity. *S. splendida* and *S. macrophylla* have been most severely influenced by these aspects.

Because the SFP has been neglected for a long time and several other aspects influencing the Illipe nut yield can be regarded as non-optimal, the potential yield of Illipe nuts is much higher than the actual production. The production figures as presented in the results have therefore been separated in 3 different models, as to provide the reader with an example of a low input, moderate and positive yield figure. The use of multiple models also enabled the possibility to present the differences in yields, depending on the difference in parameters used. The uncertainty regarding the influence of some of these parameters on the yields of a particular Shorea plantation depends on characteristics such as soil, spacing and species choice. The production of each plantation can therefore fluctuate immensely and yields presented in this study should be seen as indicative. However, because of the relatively complete amount of data on the SFP, the yield as presented in model 1 will probably closely resembles the actual yield of this plantation at the moment.

Plantation forestry

Studies and research regarding Illipe nuts in Sarawak provide in general a complete view on topics such as species description, forest type and general items as (traditional) production methods. Different studies seem to address similar topics and often quoting the same information and references. However, very few data can be found on topics such as Shorea species in plantations, costs included with (large scale) cultivation of the Illipe nut or any detailed information about the large scale cultivation of *Shorea spp*. in general. The advantage of the production of Illipe nut in plantations would be the larger scale on which the nuts would be collected and processed. With production on a large scale, production methods involved would probably be much more efficient as the original methods used by the indigenous people of Sarawak, as described on page 59 and 60 in the appendix.

6. Conclusion

Within the Shorea family there are numerous members capable of producing Illipe nuts large enough to sustain an economically interesting product. Known as the number one is *Shorea macrophylla,* with *S. pinanga* being a close second best. Furthermore, the likely presence of several not yet discovered, or recently discovered specimens could provide the genetic material which can be used to increase the production, or develop a yearly production cycle as seen by *S. atrinervosa*.

The current production of Illipe nuts is hindered by a poor knowledge of the commodity and the production of the particular Shorea species. Although some studies have been performed, there is still a general lack of knowledge about how much a certain member of the Shorea family can produce. Furthermore, apart from some studies on the effects of fertilizer on growth and fruiting, no research has been looking into other specifics that might influence the growth or production of the Illipe nut. Research on the influence of an increased crown-cover, usage of the right soil and drainage characteristics and production per age class could give some very interesting results.

In the processing of the Illipe nuts, no progress is seen at all. Methods used in the beginning of the 20^{th} century are still practiced even though improvements are available. Even after several studies (of which Connell (1968) is the best defined) repeatedly issued several key points in the processing, no improvements were seen. It is encouraging to see that even with the many hindering aspects the Illipe nut has shown to maintain the strong interest of collectors, middlemen and overseas buyers, who are forced to accept the massive fluctuation in the availability of the crop, bad quality of the product and instable prices. The possibilities to improve the quality of the crop and the transparency of the market are numerous and relatively easy to construct. With these changes, the impact on the popularity of the Illipe nut would be great.

6.1. Recommendations

This study has provided the reader with an overview of the aspects involved with the production, collection, yield (and parameters influencing the yield), processing and use/trade of the Illipe nut in Sarawak. Collection, processing and trade of the Illipe nut in Sarawak is still done on a traditional way and has remained immutable since it became an economical important product in the early 20^{th} century, even do adjustments (such as fast collection, immediate processing or drying of the nuts and hygienic storage below a moisture content of 7%, as Connell (1968)) proposed are relatively easy to establish.

Improved storage of Illipe nuts can benefit many aspects of the Illipe nut trade. Firstly, immediate and hygienic storage of dried Illipe nuts below a moisture content of 7% will diminish the possibilities of deterioration of the crop by small insects and fungus. With a safely stored crop, the owner will no longer have the urge to sell his product as fast as possible because of his fear for loss of yields (as is currently the case). This will allow him to wait until a better market price can be obtained. The temporary safe storage of the crop will also allow collectors to increase their efforts in collecting Illipe nuts in the field.

Bibliography

Anderson, J. (1963). The Flora of the Peat Swamp forests of Sarawak and Brunei, including a catalogue of all recorded species of Flowering Plants, Ferns and Fern Allies. *Gardens Bulletin, 20*, 131-228.

Anderson, J. (1975). Illipe Nuts (Shorea spp.) as Potential Agricultural Crops. In C. H.-S. J.T. Williams (Ed.), *South East Asian Plant Genetic Resources* (pp. 217-230). Bogor, Indonesia: International Board for Plant Genetic Resources.

Anderson, J. (1980). *A Checklist of the Trees of Sarawak.* (F. D. Sarawak, Ed.) Kuching, Sarawak, Malaysia: Vanguard Press Sdn. Bhd.

Anonymous. (1915). Illipé Nuts and the sources of Borneo Tallow. In D. o. Institute (Ed.), *Bulletin of the Imperial Institute of Great Britain* (Vol. 13, pp. 335-344). London, Great Britain.

Anonymous. (1920, April Saturday, 10). Illipe nuts. *The Singapore Free Press*, p. 6.

Anonymous. (1977, March 31). World Forestry Day. *Sarawak Gazette, 53*(1429), 45-47.

Anonymous. (1998, May 28). WILD LIFE PROTECTION ORDINANCE, 1998. *Sarawak Gazette*.

Appanah, S. (1985). General flowering in the climax rain forests of Southeast Asia. *Journal of Tropical Ecology, 1*, 225-240.

Appanah, S. (1993, December). Mass flowering of dipterocarp forests in the aseasonal tropics. (F. R. (FRIM), Ed.) *Journal Biosci, 18*(4), 457-474.

Appanah, S., & Turnbull, J. M. (1998). *A review of Dipterocarps, Taxonomy, ecology and silviculture.* Bogor, Indonesia: Center for International Forestry Research.

Ashton, P. S. (1964). *Ecological studies in the mixed dipterocarp forests of Brunei State* (Vol. 25). Oxford, UK: Clarendon Press.

Ashton, P. S. (1964). *Manual of the Dipterocarp trees of Brunei State.* Singapore: Oxford University Press.

Ashton, P. S. (1968). *A manual of the Dipterocarp trees of Brunei State and of Sarawak - Supplement.* Kuching, Sarawak, Malaysia: Sarawak Forestry Department.

Ashton, P. S. (1982). Dipterocarpaceae. In *Flora Malesiana* (Vol. 1, pp. 237-552).

Ashton, P. S. (1988). Dipterocarp Biology as a Window to the Understanding of Tropical Forest Structure. *The Annual Review of Ecology, Evolution, and Systematics*, p. 352.

Ashton, P. S., Givnish, T. J., & Appanah, S. (1988, July). Staggered Flowering in the Dipterocarpaceae: New Insights Into Floral Induction and the Evolution of Mast Fruiting in the Aseasonal Tropics. (A. S. Naturalists, Ed.) *The American Naturalist, 132*(1), 44-66.

Azani, A. M., Majid, N. M., & Meguro, S. (2001). Rehabilitation of Tropical Rainforests Based on Indigenous Species for Degraded Areas in Sarawak, Malaysia. In S. Kobayashi, J. Turnbull, T. Toma, T. Mori, & N. Majid (Ed.), *Rehabilitation of degraded tropical forest ecosystems. Workshop proceedings 2-4 November 1999* (pp. 142-147). Bogor, Indonesia: Center for International Forestry Research.

Baillie, I. C. (1970). *Report on the Detailed Soil Survey of the Experimental Afforestation Sites.* Soil Survey Research section, Forest Department Sarawak. Kuching: Government of Sarawak.

Bidayu women, i. K. (2013, July 11). Availability of Illipe nuts. (Q. Coolen, Interviewer)

Blicher-Mathiesen, U. (1994, July-September). Borneo Illipe, a Fat Product from Different Shorea spp. (Dipterocarpaceae). *Economic Botany, 48*(3), 231-242.

Boswell, A. B. (1940). Rainfall and the flowering of Shorea. *Malaysian Forester, 9*, 175-177.

Browne, F. G. (1955). *Forest Trees of Sarawak and Brunei and Their Products.* Kuching, Sarawak, Malaysia: Government Printing Office.

Bruenig, E. F. (1996). *Conservation and Management of Tropical Rainforests.* Cambridge, UK: CAB International.

Butt, G., & Chiew, S. P. (1982). *Guide to Site-Species Matching in Sarawak.* Forest Research report, Soils Research Unit, Forest Department Sarawak, Kuching.

Caldecott, J. (1988). A Variable Management system for the Hill forests of Sarawak, Malaysia. *Journal of Tropical Forest Science, 1*(2), 103-113.

Chai, E. O. (1998). *Aspects of a Tree Improvement Programme for Shorea macrophylla (de Vriese) Ashton in Sarawak, Malaysia.* University of Edinburgh.

Chai, E. O. (2013, May 02). Semengoh Plantation (Landeh Road). (Q. Coolen, Interviewer)

Chai, E. O., & Demies, M. (2013, May 06). Last Fruiting Event of Shorea spp. in Sarawak. (Q. Coolen, Interviewer)

Chiew, F. C., & Yaw, K. S. (Unknown). *Engkabang - A potential plantation crop tree.*

Chin, S. C. (1985, December). Agriculture and Resource Utilization in a Lowland Rainforest Kenyah Community. *The Sarawak Museum Journal, 35*(56 (New Series)), 127-235.

Cleary, M. C. (1996, May). Indigenous Trade and European Economic Intervention in North-West Borneo. *Modern Asian Studies, 30*(2), 301-324.

Connell, M. (1968). *R42 The Sarawak Illipe Nut Trade, A Post Harvest Study.* Tropical Products Institute, Research Section Forest Department. Kuching: Ministry of Overseas Development.

Connell, M. (1974, October 7-11). Succession of infestation in Illipe nuts in Sarawak -An example of a cash crop problem. (E. Brady, J. Brower, P. Hunter, E. Jay, P. Lum, H. Lund, et al., Eds.) *Proceedings of the 1st International Working Conference on Stored-Product Entomology*, 30-40.

Dallinga, J. S. (2013). *Carbon Stock and Opportunity Assessment of Shorea Plantation Forests.* Van Hall Larenstein University. Velp, Netherlands: Unpublished.

Demies, M. (2013, May 06). Illipe Nuts and Field study Details. (Q. Coolen, Interviewer)

Gillis, M. (1988). Malaysia: Public Policies and the Tropical forest. In R. Repetto, & M. Gillis, *Public Policies and the Misuse of Forest Resources* (p. 145). Cambridge: Cambridge University Press.

Golley, F. (1983). Tropical Rainforest Ecosystems. In D. W. Goodall, *Ecosystems of the World 14A.* Amsterdam: Elsevier Scientific Publishing Company.

Harrisson, T., & Salleh, A. M. (1960, July-December). Nuts and Malays on Tanjong Datu. *The Sarawak Museum Journal, 9*(15-16 (New Series)), 655-669.

Hiremath, J. A. (2004). The ecological consequences of managing forests for Non Timber Products. *Conservation & Society, 2*(2).

IPCC. (2006). *Guidelines for National Greenhouse Gas Inventories.* The Intergovernmental Panel on Climate Change (IPCC). Hayama, Japan: Institute for Global Environmental Strategies (IGES).

Iqbal, M. (1993). *International trade in non-wood forest products: An overview.* Rome, Italy: Food and Agriculture organization of the United Nations.

Iqbal, M., & Sim, E. S. (1973). Inorganic Nutrient Composition of Sarawak Illipe Nuts. (D. o. Agriculture, Ed.) *Malaysian Agricultural Journal, 49*(2), 214-222.

ITTO. (1993). *ITTO Guidelines for the Establishment and Sustainable Managment of Planted Tropical Forests.* ITTO Policy Development. Yokohama, Japan: Ac Designers Sdn. Bhd.

Janzen, D. H. (1971). Seed predation by animals. *Annual Review of Ecology, Evolution, and Systematics, 2*, 465-492.

Janzen, D. H. (1974, July). Tropical Blackwater Rivers, Animals, and Mast Fruiting by the Dipterocarpaceae. *Biotropica, 6*(2), 84-90.

Kaur, A. (1998, February). A History of Forestry in Sarawak. *Modern Asian Studies, 32*(1), 117-147.

Kershaw, S. J. (1987). Technical note: Heterogeneity in commercial contractual samples of illipe nut (Shorea spp.). *International Journal of Food Science and Technology, 22*, 67-72.

Kettle, C. J., Ghazoul, J., Ashton, P. S., Cannon, C. H., & al., L. C. (2010, October 29). Mass Fruiting in Borneo: A Missed Opportunity. (J. Sills, Ed.) *Science, 330*, 584-586.

Krishnapillay, D. (2002, June). Case study of the Tropical forest plantations in Malaysia. (M. Varmola, Ed.) *Forest Plantations Working Papers*.
Lands and Survey Department. (1953). Sarawak Divisional. *Sarawak Series nr. 5*. Kuching, Sarawak, Malaysia: Government of Sarawak.
Lawrence, D. C., Leighton, M., & Peart, D. R. (1995, February). Availability and Extraction of Forest Products in Managed and Primary Forest Around a Dayak Village in West Kalimantan, Indonesia. *Conservation Biology, 9*(1), 76-88.
Lee, H. S. (1980). Shorea pinanga Burck. flowers 6 years after planting in Research Plot No. 76. *The Malaysian Forester, 43*(1), 126-127.
Lee, H. S. (2013, June). Personal correspondence about Shorea and Field data. (Q. Coolen, Interviewer)
León, J. (1982). *Genetic Resources of Tropical Crops.* Report to GTZ - Draft, Turrialba Catie, Costa Rica.
Lieth, H., & Werger, M. J. (1989). Tropical Rain Forest Ecosystems. In D. W. Goodall, *Ecosystems of the World 14B.* Amsterdam: Elsevier Science Publishers B.V.
Lim, N. P., Tan, Y. E., Gan, K. S., & Lim, S. C. (2011). *Properties of Shorea macrophylla (Engkabang Jantong) Planted in Sarawak.* Forest Research Institute. Kepong: Reka Cetak Sdn. Bhd.
Lipp, M., & Anklam, E. (1998). Review of Cacao butter and alternative fats for use in Chocolate-part A. Compositional data. (N. a. Analytical, Ed.) *Food Chemistry, 62*(1), 73-97.
Marzalina, M. (2002). Seed Dewinger Machine - an Answer to Processing Dipterocarp Seeds: Some Preliminary results. In S. A. H. Aminah (Ed.), *Proceedings of the Seventh Round-table Conference on Dipterocarps*, (pp. 210-213). Kuala Lumpur, Malaysia.
Medway, L. (1972). Phenology of a tropical rain forest in Malaya. *Biological Journal of the Linnean Society, 4*, 117-146.
Meijer, W., & Wood, G. H. (1964). *Dipterocarps of Sabah (North Borneo).* Sabah, Malaysia: Forest Department Sandakan.
Menon, K. (1989). *Minor Forest Products: prospects for development.* Government of Indonesia, Directorate General of Forest Utilization. Rome: Food and Agriculture Organization of the United Nations.
Mertz, O., & Christensen, H. (1997). Land Use and Crop Diversity in Two Iban Communities, Sarawak, Malaysia. *Geografisk Tidsskrift, 97*, 98-109.
Mr. Chan, O. o. (2013, April 29). Availability of Illipe Nuts. (Q. Coolen, Interviewer)
Nakagawa, M., Itioka, T., Momose, K., Yumoto, T., Komai, F., Morimoto, K., et al. (2003). Resource use of insect seed predators during general flowering and seeding events in a Bornean dipterocarp rain forest. *Bulletin of Entomological Research, 93*, 455-466.
Nazri, N. A., Ahmat, N., Abdullah, M., Sidik, N. J., & Johari, S. A. (2012). Antioxidant, Antimicrobial and Cytotoxic Activities of Resveratrol Oligomers of Shorea macroptera Dyer. *Australian Journal of Basic and Applied Sciences, 6*(8), 431-436.
Neumann, R. P., & Hirsch, E. (2000). *Commercialisation of Non Timber Forest Products: Review and Analysis of Research.* Bogor, Indonesia: Center for International Forestry Research.
Noorzita, S. (1987, December 14). The potential of Illipe nut. *The New Strait Times*, p. 6.
Okwelogu, T. (1969, May 16). Maximum safe moisture content for storing teff (Eragrostis abyssinica Schrad.) and Sarawak illipe nut (Shorea gysbertsiana Burck.). *Journal of Stored Products Research, 5*, 169-172.
Padoch, C., & Peluso, N. L. (1996). Borneo People and Forests in Transition: An Introduction. *Borneo in Transition, People, Forests, Conservation and Development*, 1-9.
Panayotou, T., & Ashton, P. S. (1992). Non Timber Forest Products - A Majorn component of forest value. In T. Panayotou, & P. Ashton, *Not by Timber alone; Economics And Ecology For Sustaining Tropical Forests* (p. 82). Washington D.C.: Island Press.

Parlan, I. B. (2013, August 28). E-mail converstation about Illipe research at FRIM. (Q. Coolen, Interviewer)

Pearce, F. (1990, May 12). Hit and Run in Sarawak. *The New Scientist*(1617), pp. 24-27.

Peters, C. M. (1996). Illipe Nuts (Shorea spp.) in West Kalimantan: Use, Ecology and Management potential of an important forest resource. In C. Padoch, & N. L. Peluso, *Borneo In Transition : People, Forests, Conservation, and Development* (pp. 230-244). Kuala Lumpur: Oxford University Press.

Peters, C. M. (2008, November 3). *Illipe nut*. Retrieved August 5, 2013, from Thus I have seen: http://thusihaveseen.squarespace.com/thusihaveseen/2008/11/3/illipe-nut.html

Peters, C. M. (2008, November 4). *Illipe nut 2*. Retrieved August 5, 2013, from Thus I have seen: http://thusihaveseen.squarespace.com/thusihaveseen/2008/11/4/illipe-nut-ii.html

Peters, C. M. (2008, November 5). *Illipe nut 3*. Retrieved August 5, 2013, from Thus I have seen: http://thusihaveseen.squarespace.com/thusihaveseen/2008/11/5/illipe-nut-iii-1.html

Peters, C. M. (2013, September 4). E-mail correspondence annually flowering Shorea spp. (Q. Coolen, Interviewer)

Phang, C. (1982). *Report on Foilar Analysis of Shorea Pinanga at RP 76, Semengoh forest reserve.* Unpublished, Sarawak Forestry department.

Poore, D. (1989). *No timber without trees. Sustainability in the tropics.* London: Earthscan Publications.

Potter, L. (1996). Forest Degradation, Deforestation, and Reforestation in Kalimantan: Towards a Sustainable Land Use? *Borneo in Transition, People, Forests, Conservation and Development*, 13-40.

Raymond, W. D., & Ward, J. B. (1956). Studies on Illipe Nuts from Sarawak and the federation of Malaya. *Colonial Plants and Animal Products, 6*, 243-254.

Ridi, E. F. (1998). *Report on Survey/Inventory of Engkabang (Shorea Species).* Forest Research Department Sarawak, Kuching.

Sakai, S., Harrison, R. D., Momose, K., Kuraji, K., & Nagamasu, H. (2006, August). Irregular droughts trigger Mass flowering in Aseasonal tropical forests in Asia. *American Journal of Botany, 93*(8), 1134–1139.

Salleh, T. H. (2011). *Annual report.* Sarawak Forestry Department. Kuching: Sarawak Forestry Department.

Sellato, B. (2002). Non-timber forest products and trade in Eastern Borneo. (U. d. Provence, Ed.) *Bois et Forêts des Tropiques, 271*(1), 3,8.

Seng, T. S., & Hock, B. L. (1986). Engkabang Plantation in Sarawak. In F. Department (Ed.), *Malaysian Forestry Conference Papers , 2.* Kuching, Sarawak.

SFD. (1962 & 1979). *Annual Report.* Sarawak Forestry Institute, Sarawak Forest Research Section. Kuching: Government of Sarawak.

SFD. (1974 & 1977). *Annual Report.* Sarawak Forestry Institute, Silvicultural Section . Kuching: Government of Sarawak.

SFD. (2000). *Forest Plantations in Sarawak*. Retrieved 10 16, 2013, from http://www.forestry.sarawak.gov.my: http://www.forestry.sarawak.gov.my/page.php?id=647&menu_id=0&sub_id=244

SFD. (2006). *List of Protected plants in Sarawak*. Retrieved 9 18, 2013, from http://www.sarawakforestry.com: http://www.sarawakforestry.com/htm/snp-bc-pp.html

SFD. Semengoh F. R. Engkabang Plantation (Shorea Species). *Seed production Area - PM 51 Kota Samarahan.* Sarawak Forestry Department, Kuching, Sarawak, Malaysia.

Shariff, F. M., Amiruddin, T. H., & Bujang, E. A. (Undated). *Economics of Planting Engkabang.* Palm Oil Research Institute of Malaysia, Sarawak Forest Department.

Shivadas, P. (1968, May 20). Sarawak harvests a bumper 'Gift from heaven'. *The New Strait Times*, p. 7.

Shoko, S., Momose, K., Yumoto, T., Nagamitsu, T., Nagamasu, H., Karim, A. A., et al. (2005). Plant Reproductive Phenology and General flowering in a Mixed Dipterocarp forest. (D. W. Roubik, S. Sakai, & A. A. Karim, Eds.) *Ecological Studies, 174*, 35-50.

Shop Owner at Jalan Gambier, K. (2013, April 29). Current availability of Illipe nuts. (Q. Coolen, Interviewer)

Shukor, N. A. (2001). Status of In Situ Conservation of Commercial Tree Species In Malaysia. In B. A. Thielges, S. D. Sastrapradja, & A. Rimbawanto (Ed.), *Proceedings of the International Conference on ex situ and in situ Conservation of Commercial Tropical Trees*, (pp. 53-68). Yogyakarta.

Sim, S. (1978). *Illipe Nuts and Illipe Nuts Research in Sarawak.* Agricultural Research Centre Semongok, Department of Agriculture Sarawak.

Smythies, B. E. (1958, August 31). The Illipe Nut. *The Sarawak Gazette, 84*(1206), 146-148.

Smythies, B. E. (1960). *History of Forestry in Sarawak.*

Smythies, B. E., Browne, F. G., & Anonymous. (1908-2000). *Sarawak Annual Report.* Sarawak Forestry Institute, Sarawak Forestry Department. Kuching: Government of Sarawak.

Soepadmo, E., & Wong, K. (1995). *Tree flora of Sabah and Sarawak* (Vol. 1.). (F. R. (FRIM), Ed.) Kuala Lumpur, Malaysia: Ampang Press Sdn. Bhd.

Stanton, W. R. (1992). Tropical Forests: Botanical Dynamics, Speciation and Diversity. In I. N. L.B. Holm-Nielsen, & F. f. Conservation (Ed.), *Proceedings of a Symposium, held at the University of Aarhus, Denmark* (Vol. 19, p. 90). London, England: Academic Press.

Suzuki, E., & Gadrinab, L. U. (1988-1989). Fruit production of a Six-Year old Shorea stenoptera plantation at Haurbentes, Bogor, Indonesia. (T. F. Program, Ed.) *Biotropia, 2*, 1-7.

Symington, C. F. (1943). Foresters manual of Dipterocarps. (F. Department, Ed.) *Malayan Forest Record, 16*.

Tan, S., Primack, R. B., Chai, E. O., & Lee, H. (1987). The Silviculture of Dipterocarp trees in Sarawak, Malaysia 3, Plantation Forests. *The Malaysian Forester, 50*(1-2), 148-161.

Valkenburg, J. L. (2001). Non-Timber forest products in a changing environment. In P. a. Hillegers, *The balance between biodiversity conservation and sustainable use of tropical rain forests* (pp. 117-130). Indonesia: Tropenbos International.

Whitmore, T. (1975). *Tropical Rainforests of the Far East.* Oxford, U.K.: Oxford University Press.

Wong, S. (1988). *The Chocolaty Fat From the Borneo Illipe Trees.* Malaysia: Vivar Printing Sdn. Bhd.

Wycherley, P. R. (1973). The phenology of plants in the humid tropics. *Micronesia, 9*, 75-96.

Yap, S. (1981, April-July). Collection, Germination and Storage of Dipterocarp seeds. *The Malaysian Forester, 44*(2 & 3), 281-299.

Appendices

ANNEX I. Abbreviations and Acronyms

ARC: Agricultural Research Centre, Located at Semengok, 21 km. South of Kuching

Borneo: The island of Borneo, including the countries of Malaysia (Sabah and Sarawak), Brunei and Kalimantan (Indonesia).

Dayak: Main group of indigenous population. Broadly, the Dayak people include the Bidayuh (Land Dayak), Iban (Sea Dayak), Kenyah, Kayan, Kedayan, Murut, Penan, Bisayah, Kelabit, and other groups.

Engkabang: Generally, trees known to produce high quality Illipe nuts. See chapter on Engkabang on page 15.

Ha: Hectare

Iban: *See Dayak*

Heath forest or *Kerangas*: Heath forest is a type of tropical moist forest found in areas with acidic, sandy soils that are extremely nutrient-poor. In Malaysia, these areas are known as *Kerangas.*

Kg: Kilogram

Longhouse: Traditional large raised houses, divided into a more or less public area along one side and a row of private living quarters lined along the other side.

Malaysian Dollar/RM: The Malaysian Ringgit, formerly known as the Malaysian Dollar (until 1967) is the currency of Malaysia

Malesian region: Referring to the region of Peninsular Malaysia, Sumatra, Java, Borneo, and the Philippines

SFC: Sarawak Forestry Corporation

SFD: Sarawak Forestry Department

SFP: Semengoh Forest Plantation, or Landeh plantation. Situated near Landeh Road, in the Semengoh Forest Reserve.

SFR: Semengoh Forest Reserve, situated 20 km. South of Kuching.

Borneo
and the South East Asian region

FIGURE 13. BORNEO AND THE SOUTH EAST ASIAN REGION

ANNEX II. History of Sarawak

Sarawak, situated on the North-Western part of the island of Borneo originally fell under the domain of the Sultan of Brunei, until it became of interest to the British Government in the first half of the 19th Century. At that time, the Brunei prince Pengiran Makhota had its residence at the Sarawak River where he exported Antimony ore to Singapore. The prince provoked a resistance from the local Malays because of his taxation demands and fighting continued even after he was replaced by the Brunei sultan's uncle, Pengiran Muda Hashim.

With the help and arrival of James Brooke (an English adventurer) in 1839, the uprising was suppressed and Brooke became the new Rajah of Sarawak in 1841. Under his authority, the capital of Kuching was established and the regions territory extended. When James Brooke died in 1868, his nephew Charles continued to expand the Sarawak territory and acquired a protectorate status from the British government, while remaining an independent state. Vyner Brooke succeeded his father in 1917 until the Japanese occupation during the Pacific War. After the war, Sarawak became a crown colony of Britain until 1963, when it became part of the Malaysian federation (Kaur, 1998).

ANNEX III. Forestry in Sarawak

Until the First World War, the trade in forest products was more important than timber exports, but as the importance of timber grew, a forest department was established in 1919 by the Brooke Administration. After the Second World War, heavier exploitation of timber resources became possible and by 1960 the trade in NTFP's was eclipsed by timber exports. The history of the timber sector in Sarawak can be divided into 3 periods, starting with the monopolistic trade of the Borneo Company under Brooke's rule. It was followed by an oligopoly ownership during the colonial and post war period of foreign timber concessionaires and later converted back to monopolistic state control in the national development of Sarawak. Exploitation of timber consists mainly of the Dipterocarp family in the lowland forests and secondly on the export of Ramin (*Gonystylus bancanus*) and *Shorea albida* from the Peat Swamp forests (Kaur, 1998).

After a first timber export boom in the 60's, where logging of the Peat Swamp forests and their valuable Ramin dominated the market, the timber revenue increased from nearly €15.000 in 1930 to more than €6 million in 1960 (Kaur, 1998). Timber exports continued to become the major export product of Sarawak and the second and largest timber boom was created in 1980, when the powers of the Forestry Minister were expanded. Concessions were granted to the political allies or direct families of the ruling elite. From the total of 6.7 million hectares of forest concession in Sarawak in 1987, 42% was controlled by 2 leading political figures or their family and it is likely that the rest was controlled by their friends (Gillis, 1988).

The gap in the international timber trade created by the deforestation in Thailand and Indonesia's ban on the export of logs in 1987 was filled by Sarawak and timber exports increases rapidly from a total timber revenue of €50 million in 1972 to a total of €450 million in 1982. The timber business in Sarawak during this period was described as a "grab and run philosophy" and the Forest Ordinance, which was regarded as to protect the forests for the good of the state as a whole, offered little protection (Gillis, 1988); (Pearce, 1990). Answering the growing criticism from international organizations concerning the vigorous deforestation in Sarawak, the Sarawak Chief Minister invited the ITTO in 1989 to assess the sustainability of its forestry policy. The ITTO's Report (1990), supported the state forest management policies, but recommended a reduction in the rate of logging (Kaur, 1998).

ANNEX IV. Description of *Shorea spp.* present in the Semengoh forest reserve

TABLE 15. DISTRIBUTION AND SOIL REQUIREMENTS OF THE *SHOREA SPP.* IN THE SFR.

Vernacular name	S. macrophylla (De Vriese) Ashton	S. splendida (De Vriese) Ashton	S. stenoptera Burck	S. pinanga Scheff.	S. palembanica Miq.	S. hemsleyana (Miq.) King
Distribution	Endemic to Borneo, locally common in the Northern and central parts, becoming less frequent to the East	Localized distribution in West Sarawak and West Kalimantan	West Kalimantan to West Sarawak	Throughout Borneo, but rare in Sabah and Brunei	West Malaysia, East Sumatra and Western and Central Borneo	Scattered and rare occurrence in Peninsular Malaysia and North West Borneo
Soil requirements	Mainly riparian and locally abundant on deep clay alluvium	Moist deep clay or loam alluvial soils.	Mainly poor soils such as Heath forests (*Kerangas*). Absent from peat swamps.	Deep, upland soils on hills lopes or ridge tops up to 700 meters altitude. Rare on clay alluvium.	Rich clay alluvium and low undulating land.	Leached sandy soils and shallow swamps

Shorea macrophylla (De Vriese) Ashton

S. macrophylla is the most important species of Shorea in the export supply of the Illipe nuts (Anderson, 1975); (Butt & Chiew, 1982); (Blicher-Mathiesen, 1994), it is estimated that 85 to 90% of the crop is derived from this species (Butt & Chiew, 1982) (Sim, 1978) (Smythies, 1958). The local name is Engkabang Jantong, although Kawang Jantung is also accepted and it has also been recorded as; Engkabang amat, Engkabang ayer, Engkabang ringgit and Abang taha (Browne, 1955). Translated from Malay, Jantung means 'heart', referring to the shape of the winged seeds (Lee H. S., 2013). This species was first named Shorea gysbertsiana Burck, when in 1962 Ashton argued that a sterile specimen of Hopea macrophylla (de Vriese) belongs to Shorea gysbertsiana. In the absence of the type specimen at the Leiden herbarium for confirmation, the name *Shorea macrophylla* (de Vriese) was adopted as a combination from *Shorea gysbertsiana* and *Hopea macrophylla* (Chai E. O., 1998).

Although the tree produces a very large and good quality nut with an average size of fruits of 4.5cm x 3.0cm (Shariff, Amiruddin, & Bujang, Undated), the timber has a poor quality compared to other Shorea species, but trees are reaching 50-60 cm DBH in 20-23 years (Meijer & Wood, 1964); (Chai E. O., 1998). It can attain a maximum height of 50 meters and a diameter of 1.27 meter (Butt & Chiew, 1982). This is possibly the fastest growing among the Shorea (Browne, 1955). *S. macrophylla* is almost free from heart-rot (a common problem in the Borneo timber industry) which adds to the popularity as a timber species (Chai E. O., 1998).

Besides its natural distribution in the forest, many trees are found scattered next to (former) rural areas and longhouses, where they were planted for the Illipe nuts. *S. macrophylla* produces the largest nut of all Shorea species, and also has the advantage of being riverine, which makes it easier for people to collect (Smythies, 1958); (Sim, 1978). A tree planted at Kepong, Malaysia in 1935 fruited heavily in 1952, after 17 years (Smythies, 1958), although Browne (1955) reports flowering starts at an age of about 15 to 16 years. The trees in the SFP (planted in 1936) were recorded fruiting after 26 years (Sim, 1978).

Shorea splendida (De Vriese) Ashton

S. splendida was originally named *S. martiniana* Scheff. (Browne, 1955). The local name is Engkabang Bintang, Bintang meaning round or spherical in Bahasa, referring to the shape of the nuts (Lee H. S., 2013); other names include Engkabang Martin (Anderson, 1980), Kawang Bintang, Kawang Martin (Anderson, 1975) and Tengkawang Rambai in Kalimantan (Peters, 1996). It is closely related to *S. macrophylla*, occurring in the same habitat, being mainly riparian (Browne, 1955). The tree is locally abundant on rich clay and periodically flooded alluvium, but lower slopes which are imperfectly to moderately well-drained can also be included in its habitat. Historically the timber has not been utilized since the tree is usually protected by traditional rights (Butt & Chiew, 1982). It produces a fairly large nut with a good reputation (Smythies, 1958). The tree might be more common than *S. macrophylla* and is one of the most important Illipe nut producers (Peters, 1996).

Shorea stenoptera Burck

S. stenoptera, with its local name Engkabang Rusa, where Rusa means 'deer' in Bahasa Malay, which refers to the size of the testicles of the animal compared to the nut size (Lee H. S., 2013). It is also called Engkabang Kerangas by the Iban as it is fairly common on the *Kerangas* soils, on which it differs from the rest of the Engkabang group. It produces a medium to large sized nut and a light red Meranti timber (Harrisson & Salleh, 1960); (Anderson, 1975).

This characteristic tree is usually found scattered in its habitat, but can be locally frequent on groundwater podsols in heath forest, terraces and plateaus and on periodically flooded sandy alluvium. The tree is a less important timber tree (Browne, 1955). It is however considered one of the most important Illipe nut producers in Sarawak. (Butt & Chiew, 1982). Anderson (1975) mentions the presence of a genotype of *S. stenoptera* from Palai Kerangan in the Kapuas region in West Kalimantan which begins flowering and fruiting at an age of 2 years after planting, at a height of 4-6 meters. After reports of this species producing fruits annually at such an early age, the original Haurbentes plantation (West Java) of 15 to 20 trees was extended with 400 ha. This *S. stenoptera* forma Burck is furthermore widespread in the region and planted extensively by the locals. The locality of this genotype is given in Figure 17 in the appendix. Research performed by the Sarawak Land Development Board in Miri showed that in a plantation *S. stenoptera* forma Burck flowered at 1.5 years and fruited annually (Sim, 1978).

Shorea pinanga Scheff.

S. pinanga Scheff. is locally named Engkabang Langai Bukit, but other names include Kawang Langai Bukit (Sim, 1978) and Tengkawang Tebar or Layar in Kalimantan (Peters, 1996). It is a medium to large tree, reaching 50 m. tall, with a diameter of 1.27 meter. In Sarawak it is one of the most common members of the Engkabang group (Butt & Chiew, 1982). It has a medium sized nut and produces a light red Meranti (Sim, 1978). The tree has a large potential as a timber species because of its low percentage of heart rot (Ashton, 1968). The soil requirements are deep, upland soils on hills lopes or ridge tops (Butt & Chiew, 1982). Phang (1982) states that imperfectly or poor drained sites on floodplains or lower slopes should be avoided.

S. pinanga has been reported to flower as early as 6 years after planting by Lee (1980), who studied the influence of fertilization on the flowering behavior of Shorea. Lee reported a general, but not significant effect on the flowering in the fertilized plots but unfortunately subsequent research has not been continued (Lee H. S., 2013). *S. pinanga* can be considered as the second important Illipe nut producing species in Sarawak (Chin, 1985).

Shorea palembanica Miq.

S. palembanica is locally named Engkabang Asu or Kawang Asu, which is Malay for dog and refers to the size of the testicles (Lee H. S., 2013). Other names include; Pelepak, Majau or Perawan Paya and Tengkawang Majau in Kalimantan (Peters, 1996). The tree can be found on the lower slopes of the evergreen tropical lowland rainforest (Blicher-Mathiesen, 1994). *S. palembanica* produces a medium sized, but important source of Illipe nut and a light red Meranti timber (Sim, 1978). The species is essentially riparian and favors low lying land, where it can grow up to a large tree and can be seen overhanging the banks of streams (Browne, 1955). This species produces the smallest nuts, the lowest fat percentage and yield per hectare of the Shorea species presented in this study. Although *S. palembanica* can also be found in Peninsular Malaysia, no collection of the Illipe nuts is known in that region (Blicher-Mathiesen, 1994)

Shorea hemsleyana (Miq.) King

S. hemsleyana is locally known as Engkabang Gading. Anderson (1975) describes the species as a secondary Illipe nut producer, mainly because of the smaller size of the nut, although Harrisson (1960) and Connell (1968) report a rather large sized nut and state the inaccessibility of habitat, as it is found often scattered on swampy land, as the main reason it is not collected as frequent as other species of the Engkabang group.

Because of its inaccessible occurrence, the tree has little interest from collectors and is therefore often ignored in literature. No information about production per hectare or fat content is currently available. Although Iqbal (1973) describes the species as *S. seminis*, the data is extracted from a study in the SFP, where *S. seminis* was not planted at that time. However, *S. hemsleyana* is not mentioned by Iqbal, but was the only other Shorea species planted in the SFP at that time and will therefore be assumed as the right species. Data from this study describes the nut of *S. hemsleyana* as a small ovoid nut with a mean fresh weight of 4.5 grams.

ANNEX V. Shorea plantations in Sarawak

TABLE 16. SHOREA PLANTATIONS IN SARAWAK, MALAYSIA

Species	Plantation / Organisation	Year Planted	Study objective	Remarks	Plot size in HA.	Source
S. splendida **(De Vr.) Ashton**	SFP	1926	Observe fruiting under close canopy conditions		0,11	(Seng & Hock, 1986)
	SFP	1929	Growth, flowering and fruiting	Plot nr. 10	0,44	
S. hemsleyana **(Mig.) King**	SFP	1935	As above.	First fruiting 1974	2,19	(Sim, 1978); (Seng & Hock, 1986)
S. pinanga **Burck**	SFP	1935	As above.	First fruiting 1970	0,81	
S. macrophylla **(De Vr.) Ashton**	SFP	1936	As above.	First fruiting 1962	1,62	
S. splendida **(De Vr.) Ashton**	SFP	1936	As above.	First fruiting 1970	1,34	
S. stenoptera **Burck**	SFP	1940	As above.	First fruiting 1970	0,97	
S. splendida **(De Vr.) Ashton**	SFP	1940	As above.		0,81	(Seng & Hock, 1986)
S. palembanica **Mig.**	SFP	1940	As above.	First fruiting 1970	0,81	(Sim, 1978); (Seng & Hock, 1986)
S. macrophylla	SFP	1962	As above.		8,1	
	SFP	1968	As above.		14,16	
	SFP	1970	Effects of poisoning and seed planting		4	(Sim, 1978)
S. macrophylla*; *S. pinanga	SFP	1973	Effect of compound fertilizer on Growth, Nut yield and flowering	Split plots (fertilizer-non fertilizer)	12,96	(Sim, 1978); (Seng & Hock, 1986)
S. hemsleyana **King ex Foxw.**	SFP	1975	Performance in plantation		9,6	

S. macrophylla*; *S. stenoptera*; *S. splendida	ARC	1975	-	-	-	(Sim, 1978)
S. macrophylla*; *S. splendida	SFP	1976/ 1977	-	192 trees *S. macrophylla*; 92 trees *S. splendida*; 168 trees Shorea sp.	-	
S. stenoptera*; *S. stenoptera* Burck; *S. pinanga*; *S. compressa	-	1975-1980	-	*S. stenoptera* Burck flower at age 1.5 years and fruits annually	-	
***S. macrophylla* (De Vr.) Ashton**	Gunung Gading	1980	Reforestation and Enrichment planting		21,2	(Seng & Hock, 1986)
	SFP	1980	As above.		1	
	Selang Forest Reserve	1980			7,3	
	Niah Forest Reserve	1980			2,3	
	Gunung Gading	1980			30,7	
	Selang Forest Reserve	1980			2,2	
***S. pinanga* Scheff**	Gunung Gading	1980			10,4	
	SFP	1980			1,3	
	Selang Forest Reserve	1980			1,1	
***S. stenoptera* Burck**	Gunung Gading	1980			8,7	
	Selang Forest Reserve	1980			1,6	
***S. palembanica* Mig.**	Gunung Gading	1980			2,9	
	Selang Forest Reserve	1980			1,1	
***S. macrophylla* (De Vr.) Ashton**	Sabal Plantation	1982			72,1	
	Niah Forest Reserve	1982			59,6	
	Sabal Plantation	1982			5,7	

Shorea spp.	Timber concession of Rejang Wood Sdn. Bhd.	1982	Planted for timber supply		35	
	Saravest Sdn. Bhd.	1982	As above.		1,9	
	TRIPLEX Sarawak Forest Logging	1982	As above.		1,5	
***S. macrophylla* (De Vr.) Ashton**	Sabal Plantation	1983	Reforestation and Enrichment planting		45	
	Labang Forest Reserve	1983	As above.		36,6	
	Sabal Plantation	1984	As above.		36	
	Sabal Plantation	1985	As above.		46,9	
	Sawai Forest Reserve	1985	As above.		5	
S. stenoptera Burck	*Haurbentes, Bogor, West Java*	*1940, 1970*	*Flowering and fruiting behavior*	*Fruiting annually starting at age of 1-2 years.*	*400*	(Sim, 1978)

ANNEX VI. Yield Semengoh plantation in 1979

Flowering observed early as June. Seed collection organized on 19.11.79, lasting for 4 weeks. Fruits were not sold but used as seed material (SFD, 1962 & 1979). This year's crop can be described as a moderate year.

TABLE 17. ILLIPE NUT YIELD IN THE SFP IN 1979 (SFD, 1962 & 1979)

Plot nr.	Species	Area in hectares	No. Of fruits coll.	(Dry) Yield per tree/year	Dry Yield per hectare
7	***S. macrophylla***	**1,62**	**16.111**	**2,6 kg**	**199.9 kg**
9,13	***S. splendida***	**2,26**	**16.523**	**0,7 kg**	**77.9 kg**
5C	***S. pinanga***	**0,81**	**17.663**	**1,4 kg**	**167.1 kg**
12	***S. palembanica***	**0,81**	**21.687**	**5,8 kg**	**249.3 kg**
14	***S. stenoptera***	**0,97**	**16.427**	**0,5 kg**	**66.7 kg**

ANNEX VII. Yield model values

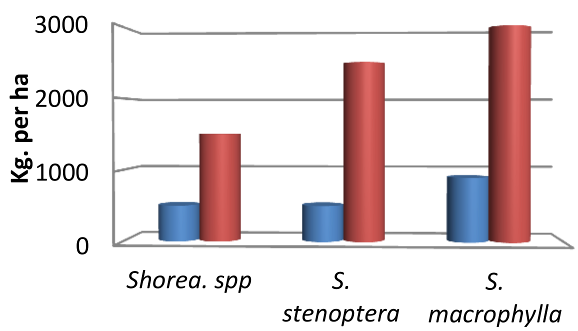
TABLE 18. ACTUAL VALUES OF ILLIPE NUT YIELD IN THE SFP OVER A 10-YEAR PERIOD IN KG.

	1	2	3	4	5	6	7	8	9	10
S. macrophylla	1.240		1.155	126		118	114		106	900
S. stenoptera	753		738	60		59	58		57	688
S. splendida	435		405	49		46	44		41	316
S. palembanica	392		384	246		242	239		234	358
S. pinanga	2.375		2.328	169		166	164		161	2.170
S. hemsleyana	703		689	442		434	429		421	643

TABLE 20. TOTAL YIELD PER HECTARE PER TREE FOR MODEL 1. (CALCULATED FROM TABLE 17)

Species	production per ha
S. macrophylla	375,85
S. stenoptera	241,47
S. splendida	133,58
S. palembanica	209,50
S. pinanga	753,24
S. hemsleyana	376,17
Average	348,30

TABLE 19. ILLIPE NUT YIELD IN A MODERATE AND MAST FRUITING YEAR (MODEL 2)



	Shorea . spp	S. stenop tera	S. macro phylla
Moderate year	500	500	900
Mast year	1500	2500	3000

TABLE 21. YIELD PER TREE FOR MODEL 2.

	Yield (kg/tree) Moderate Year	Yield (kg/tree) Mast Year
S. macrophylla	18	60
S. stenoptera	10	50
Shorea spp.	10	30

TABLE 22. YIELD PER TREE FOR MODEL 3.

	Yield (kg/tree) Moderate Year	Yield (kg/tree) Mast Year
Shorea spp.	100	400

TABLE 23. ACTUAL DATA OF MODEL 1 -3 (IN KG), FROM FIGURE 7.

Sequence	C	A	C	B	A	B	B	A	B	C
(Model 1.) *S. palembanica*	392		384	246		242	239		234	358
(Model 1.) *S. splendida*	435		405	49		46	44		41	316
(Model 1.) *S. hemsleyana*	703		689	442		434	429		421	643
(Model 1.) *S. stenoptera*	753		738	60		59	58		57	688
(Model 1.) *S. macrophylla*	1240		1155	126		118	114		106	900
(Model 1.) *S. pinanga*	2375		2328	169		166	164		161	2170
(Model 2.) Other *Shorea spp.*	1500		1500	500		500	500		500	1500
(Model 2.) *S. stenoptera*	2500		2500	500		500	500		500	2500
(Model 2.) *S. macrophylla*	3000		3000	900		900	900		900	3000
(Model 3.) *Shorea spp.*	8000		8000	2000		2000	2000		2000	8000
Years	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

ANNEX VIII. Kuching region

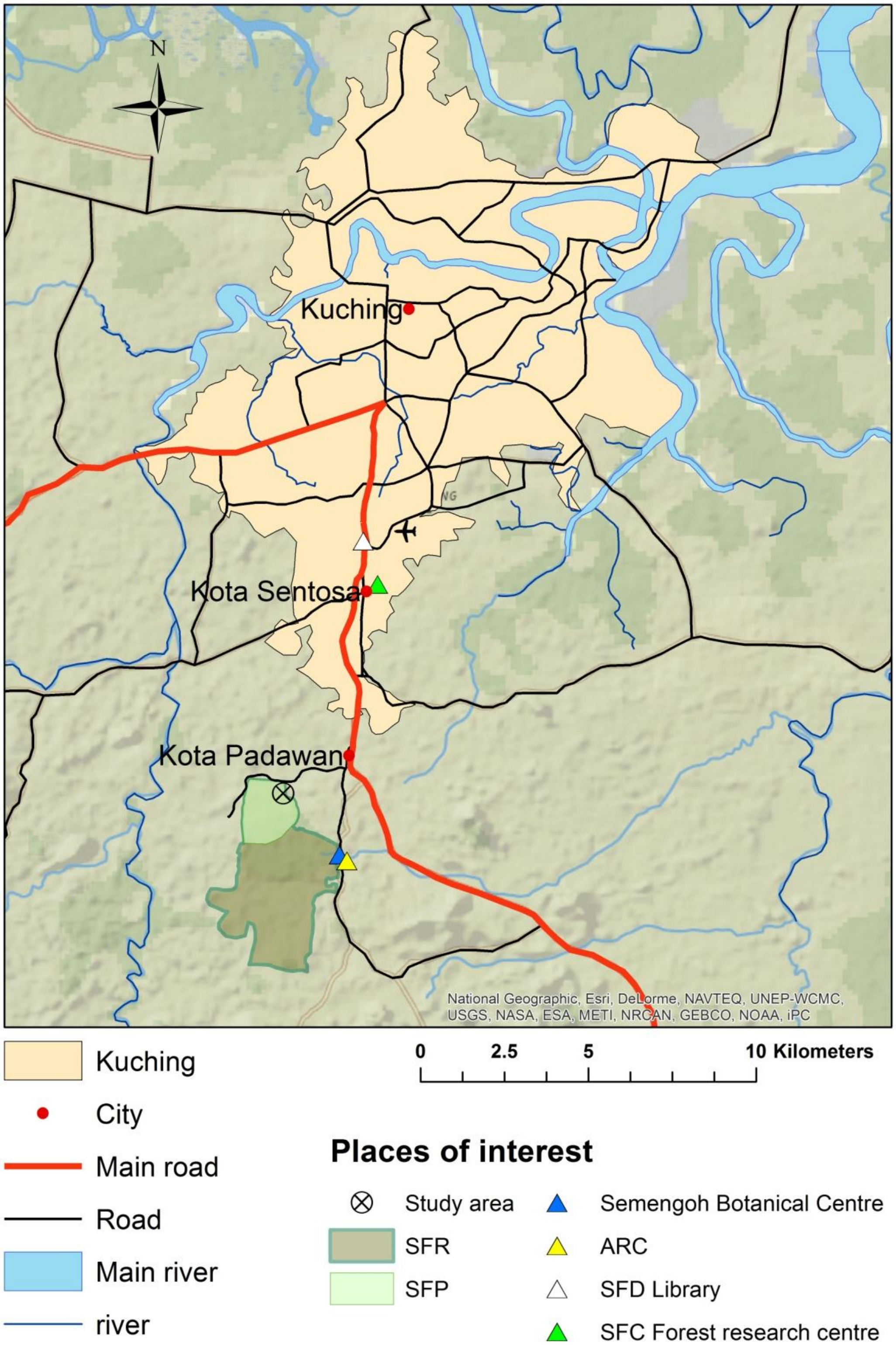


FIGURE 14. THE KUCHING REGION INCLUDING RELEVANT PLACES OF INTEREST.

ANNEX IX. Map of the Semengoh Forest Plantation

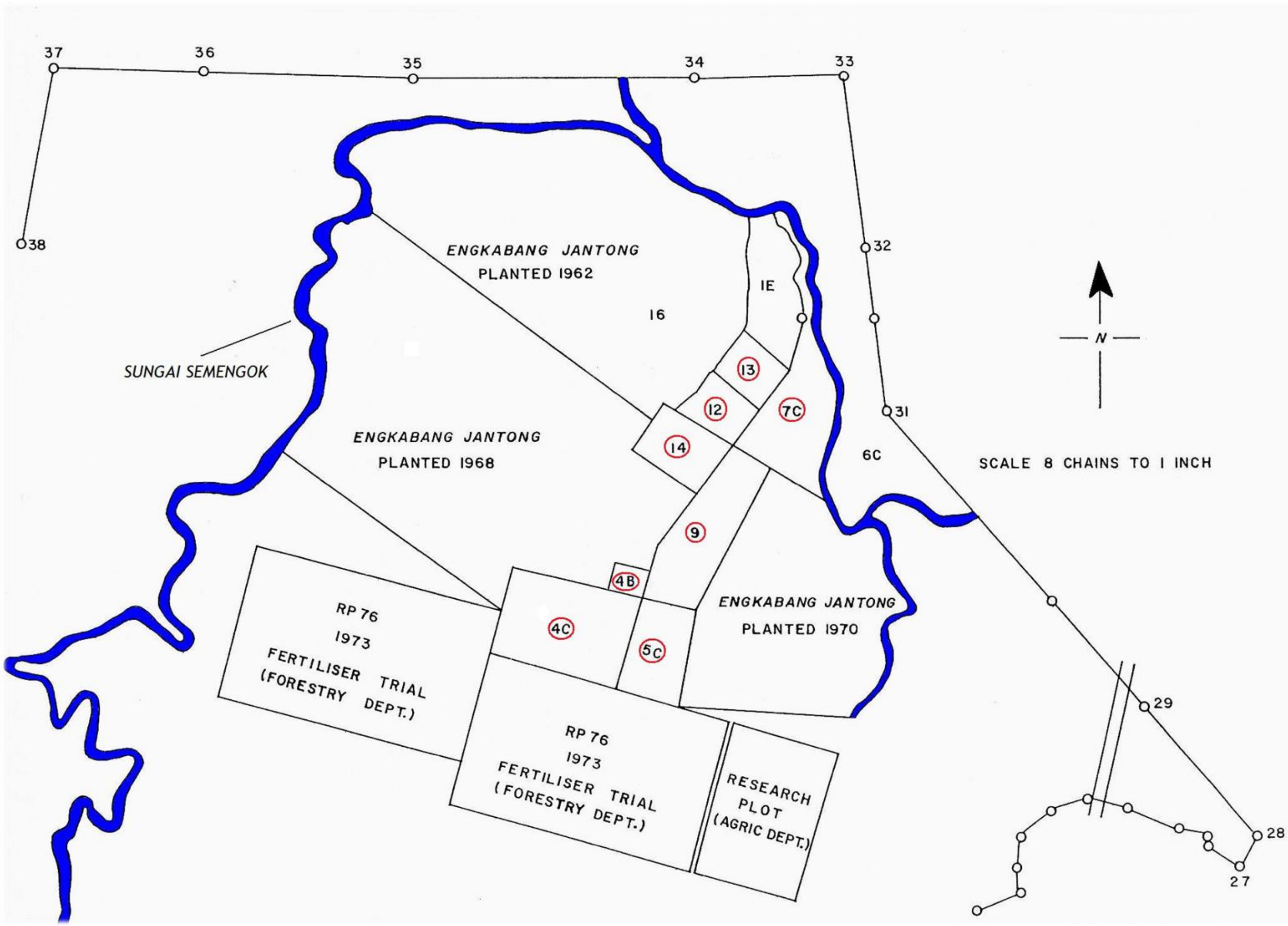


FIGURE 15. MAP OF THE SFP (SIM, 1978)

ANNEX X. Sarawak Division map

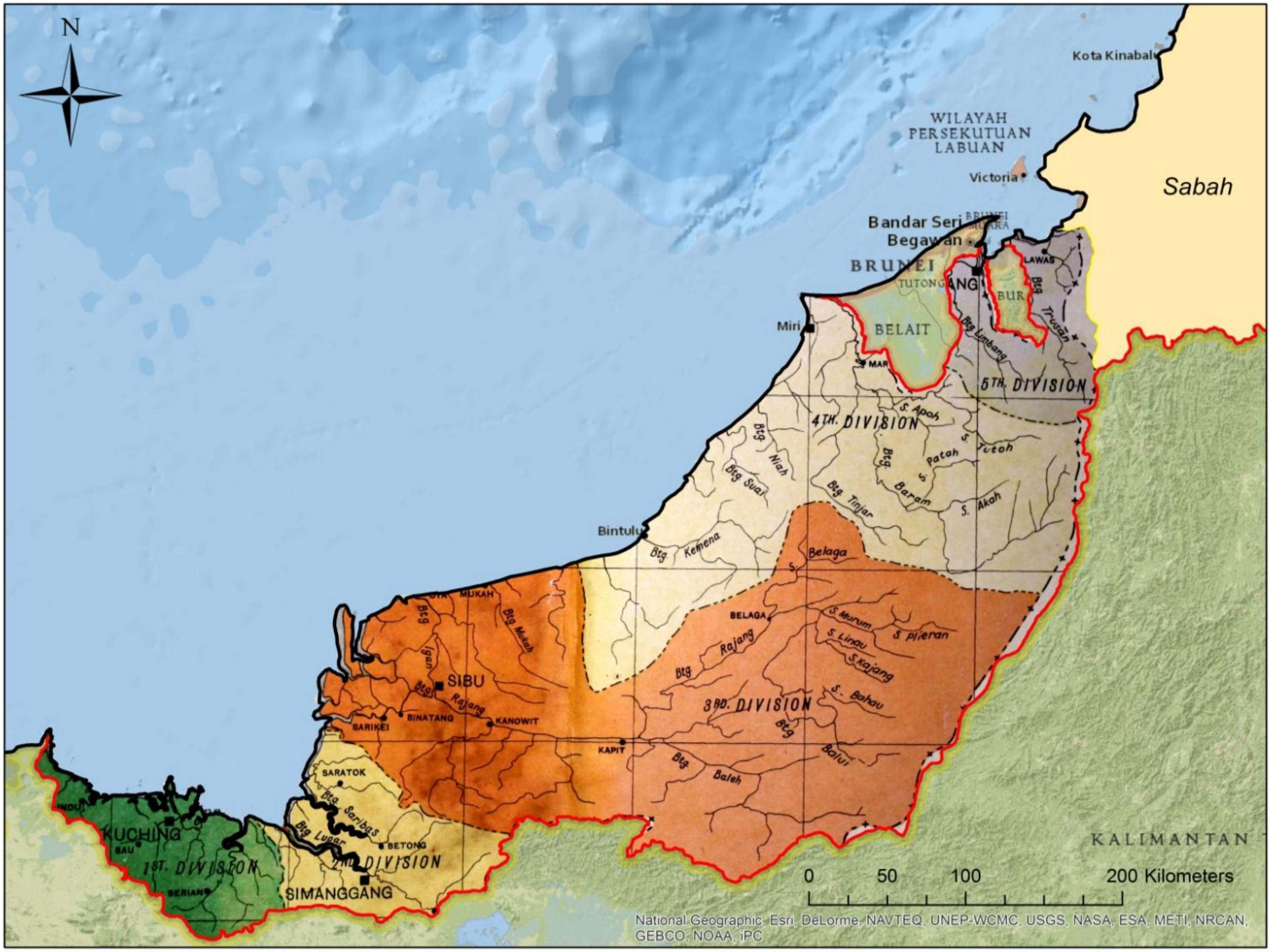


FIGURE 16. SARAWAK DIVISIONAL MAP, EDITED FROM (LANDS AND SURVEY DEPARTMENT, 1953).

ANNEX XI. Origin of the genotype *Shorea stenoptera* Burck

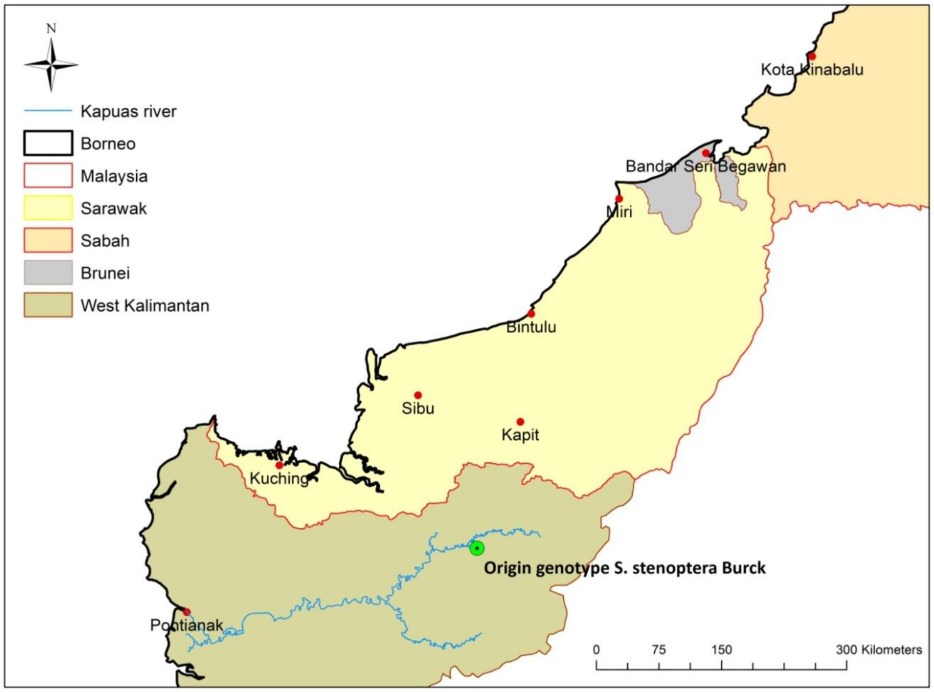


FIGURE 17. LOCALITY OF THE ORIGINAL GENOTYPE OF *S. STENOPTERA* BURCK (ANDERSON, 1975).

ANNEX XII. Potential study sites planted with *Shorea spp.* in Sarawak

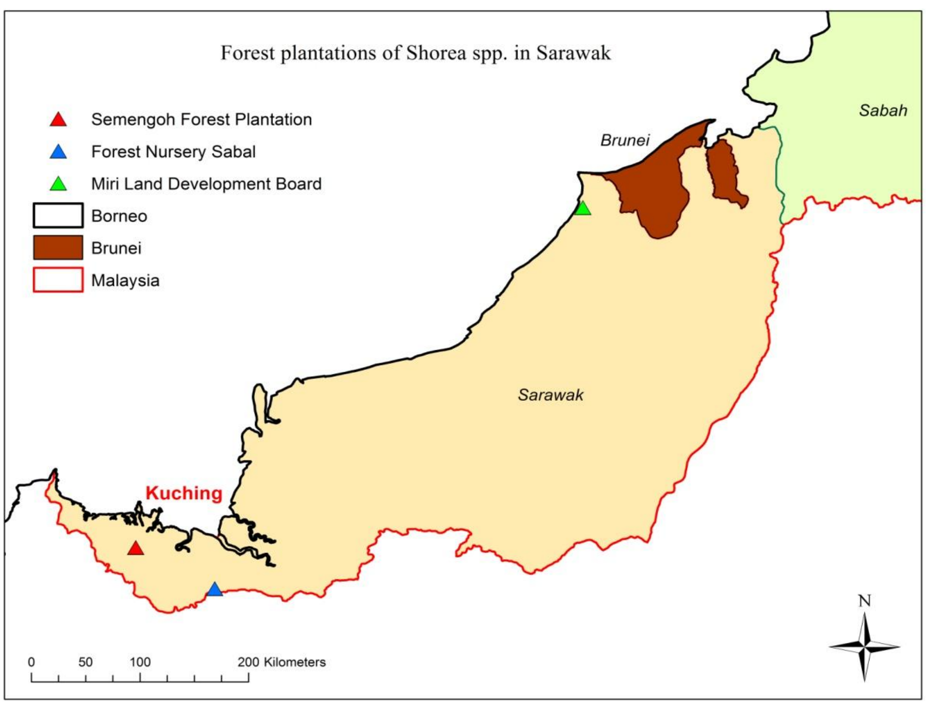


FIGURE 18. FOREST PLANTATIONS WITH *SHOREA SPP.* MAINTAINED IN SARAWAK.

ANNEX XIII. Local recipes of Illipe nuts

Although the varieties and possibilities are probably endless, these are some recipes mentioned by Harrisson (1960) where Illipe nuts are used in local meals. The term "Engkabang" will be used instead of Illipe, as this is the local translation in Bahasa Malay.

- *Engkabang with salted Durian (tempoyak)*

The wet, ripe nut is de-winged and shelled and properly washed in water; then rubbed with the salted Durian. This is a delicacy for the Sarawak Malays, known as "*Berulam Engkabang dengan tampoyak"*.

- *Engkabang with prawn paste (Sambal belachan)*

The preparation is similar to the recipe above, but this time the nuts are rubbed with the shrimp paste. This delicacy is known as "*Berulam Engkabang dengan sambal belachan"*.

- *Sambal goreng Engkabang*

Wet and cleaned nuts are crushed to pieces in a stone (*lesong batu*) or wood (*Engkalan*) pounder. The crushed nuts are then mixed with prawns, onion, red chili and prawn pastes (*Sambal belachan*). The mixture is fried in a pan using coconut oil, while thoroughly stirred until all is well cooked and sizzling. The use of a coconut shell instead is said to produce a superior taste compared to any sort of pan.

- *Pais Engkabang*

Wet and cleaned nuts are folded in the young leaves of Coconut or Nipah palm (*Nypha fruticans*). This is placed above a stove and heated gently for some time until it is cooked delicate brown. The dish must be served real hot.

- *Pekasam Engkabang*

Wet and cleaned nuts are boiled for 30 minutes or some time and then placed in a jar, where it is mixed with uncooked prawns, cooked or fried rice and some raw salt. The jar is then tightly shut with a cloth for 4 to 5 days, when it is ready for eating.

- *Pure Engkabang oil (Minyak Engkabang)*

Well dried nuts are pounded into a powder or dust and fried for 30 minutes or so. The hot fried powder is then poured into a bag of rattan, containing approximately 0.5 kg and placed under pressure (of a wooden press) to squeeze out the oil. This liquid is later poured into a bamboo, so that it turns hard when cooled. This "*Minyak Engkabang"* is yellowish colored, similar to wax and is used for frying fish or rice etc. by knocking the hard lump in pieces and then heated so it will turn liquid.

- *Hot cooked rice with oil (Nasi goreng minyak Engkabang)*

Hot and cooked rice is simply rubbed with a hard lump of *Minyak Engkabang* which will instantly melt.

ANNEX XIV. Traditional collection of the Illipe nut

Originally, Illipe nuts were collected by the local inhabitants. For these communities, that supported themselves with shifting agriculture, rice paddies and jungle products, the Illipe nut was an occasional and very welcome cash income and the mast fruiting can be seen as an important event (Panayotou & Ashton, 1992). The event, with such a large economic impact for Sarawak, generating millions of dollars in good years, is kept strictly local and with minimal governmental influence, based on indigenous and Malay collectors and later Chinese middlemen, with controls and government interests coming only in the late stage (Harrisson & Salleh, 1960).

Occasional planting of 'Engkabang' also occurs, usually in forest orchards. In these orchards, or Tembawang, the trees are usually mixed with other useful trees, such as Durian (*Durio zibethinus*) and Rambutan (*Nephelium lappaceum*). Although a forest orchard suggests good care is given to the trees in it, proper cultivation cannot be said to be undertaken at all. After planting, no attention is given to it until it begins to yield fruit and in Sarawak it is hard to point out trees that were initially planted or naturally regenerated (Anonymous, 1915) .

Noorzita (1987) describes that at times the Engkabang trees are bearing mature fruit, whole families are leaving their longhouses as soon as the wind starts blowing through the tree-tops because they know the fruits will have fallen (Sim, 1978). The more wind, the larger is the quantity of nuts, and a crop of Illipe nuts is therefore often referred to as a 'windfall' (Harrisson & Salleh, 1960); (Connell, 1968). At the height of a fruiting season, collectors may build temporary huts and camp near the fruiting trees to be able to collect more efficiently (Chin, 1985), not only men, but also women and children are joining in these parties (Harrisson & Salleh, 1960). Transport is usually done by boats or by foot to trees that are known (Sim, 1978). Trees and Shorea species suitable for collection are usually selected based on its reachability, ease of collecting and size of the nuts (Connell, 1974). Chin (1985) describes that the locality of Illipe nut trees within 2 hours walk away from longhouses or rivers large enough for boats are known to collectors. It is considered not practical to collect from more distant trees.

The nuts are collected from the ground, but when trees grow near the water, as much of the Shorea are known to do, nuts are collected from the water itself. For collection from the water, collection is done by putting a (fishing) net or temporary fence across the river and trapping the nuts as they float down, but sometimes bamboo poles are used as a barrier, which are frequently checked by collectors in longboats, who can than easily scoop the nuts out of the water (Connell, 1968). Because of this, *S. macrophylla* has always been the most favored tree for Illipe nuts, as it has both the largest nuts and grows usually alongside creeks, where the fallen nuts can easily be lifted out of the water (Connell, 1974). In more recent years, 1970's and onwards, the harvest has been facilitated by better communications and the increased use of outboard engines, which enabled collectors to access the more remote areas (Anderson, 1975).

In general, other species of Illipe nuts are collected from the forest floor, where sometimes the ground beneath the trees is slashed in order to facilitate easier collection from the ground (Chin, 1985); (Connell, 1968). Collected nuts are placed in empty oil barrels or other handy receptacles (Noorzita, 1987). More traditional collecting baskets are the 'Salabit' (Anonymous, 1977); (Sim, 1978) or 'Ki'ba' (Chin, 1985), which is made of split rattan and carried on the back by 2 shoulder straps (see Figure 19).

ANNEX XV. Traditional Illipe nut collection basket

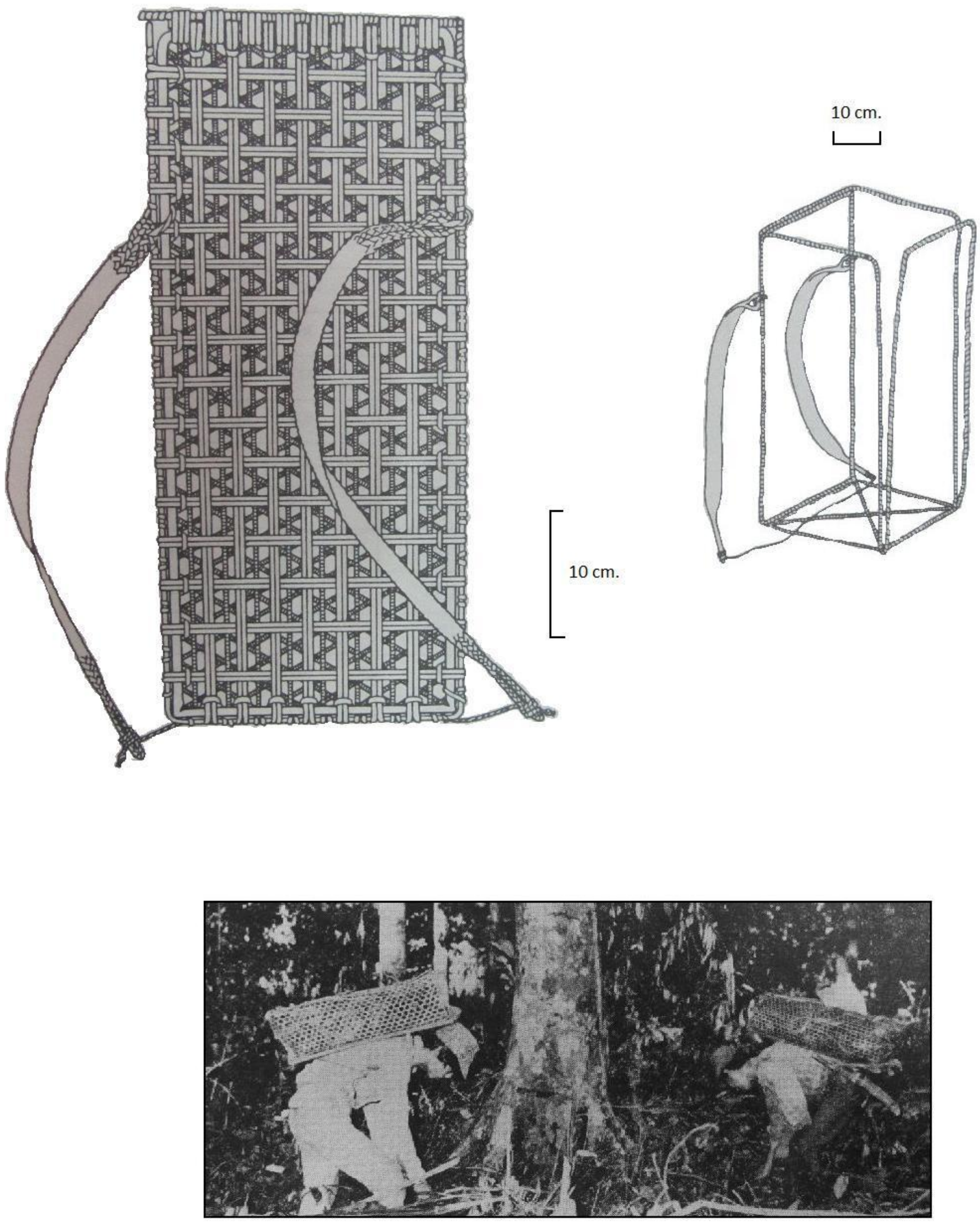


FIGURE 19. TRADITIONAL KI'BA BASKET FOR THE COLLECTION OF ILLIPE NUTS (ANONYMOUS, 1977); (CHIN, 1985)

ANNEX XVI. Traditional processing methods

The “immersion method” produces the “black nuts” which have a better reputation on the market because of their higher fat percentage. Nuts are packed in crates of bamboo or rattan (Calamus sp.) and fully immersed in rivers or streams. Complete immersion has the benefit of killing insects and making it easier to shell the nuts later (Anderson, 1975). Connell (1968) describes that the submersion of the nuts usually takes several weeks, in which the nuts germinate and burst out of their shell. Submersion for longer than 30 to 40 days will cause a loss of quality because of decay. After the immersion, the nuts are sun dried for about 5 to 7 days, which requires 4 to 6 hours of sunny weather. Sun drying is traditionally done on the outside platform (*Tanju*) of the longhouse, on rattan mats (*Biday*) or elevated platforms. For this, nuts are shelled and broken in 2 halves (Anderson, 1975); (Smythies, 1958).

The “kiln drying method” is done by placing the nuts on a rattan mat on top of a constructed platform while roasting them over a slow burning fire until dry, about 36 hours. This method produces the less favored “brown nuts” (Anderson, 1975). While smoking, the nuts are turned over and over in order to equally dry them on all sides (Harrisson & Salleh, 1960). Fires should be kept low because higher temperatures (above 70°C) can cause the oil to leak out of the nuts (Connell, 1968). This smoking process requires day and night attention and is done on days there is no collection possible (Anonymous, 1977). Nuts are sometimes shelled of their hard skin before drying, using a machete (*Parang*) (Chin, 1985). However, shelling is done easier afterwards, as the fire will ease the removal of the shells. The loss in weight from shelling and drying of the nuts is said to be 40% (Harrisson & Salleh, 1960).

Connell (1968) describes 4 different methods, divided in the immersion method and kiln-drying method as described earlier, adding a basic and burying method. The basic method includes only the shelling of the nuts after which they are dried in the sun. The burying method, which is reported to be used in Kalimantan, consists of the immediate burial of the freshly fallen nuts in shallow pits, stimulating germination. When germinated nuts are later on dug up, they are easily shelled and sun dried. Other methods described are boiling, which prevents germination of the nut and eases the decortication of the shell. Sometimes the nuts are put in a damp place and allowed to germinate, after which the shells are removed and the sprouts broken off. Then, nuts are usually sun dried. The last process however will decrease the fat percentage in the nut significantly because of the germination (Anonymous, 1915).