Final Technical Report No. 1

Initiating Development of Sustainable Wood Supply from Energy Forest Plantations

ITTO Project PD 737/14 Rev.2 (I)

Developing Supply Capacity of Wood-Based Biomass Energy
through Improved Enabling Conditions and Efficient Utilization of Degraded Forest Lands
involving Local Communities in North Sumatra Province of Indonesia

Jakarta, October 2021

The Ministry of Environment and Forestry of Indonesia (MoEF)
Directorate General of Sustainable Forest Management (PHL)
Directorate of Production Forest Development (UHP)
Indonesian Sawmill and Woodworking Association (ISWA)
The International Tropical Timber Organization (ITTO)

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Initiating Development of Sustainable Wood Supply from Energy Forest Plantations

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Executed by:

Directorate of Production Forest Development (UHP)
Directorate General of Sustainable Production Forest Management (PHPL)
The Ministry of Environment and Forestry of Indonesia (KLHK)

In collaboration with:

The Indonesian Sawmill and Woodworking Association (ISWA)

With the assistance of:

The International Tropical Timber Organization (ITTO)

Jakarta, October 2021

Project Title	: Developing Supply Capacity of Wood-Based Biomass Energy through Improved Enabling Conditions and Efficient Utilization of Degraded Forest Lands Involving Local Communities in North Sumatra Province of Indonesia
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List of Abbreviations

ANFRI	Aek Nauli Forestry Research Institute
EFP	Energy Forest Plantation
FMU	Forest Management Unit
FRBD	Factorial Randomized Block Design
Hum	Humbang Hasundutan
ISWA	Indonesian Sawmill and Woodworking Asociation
ITTO	International Tropical Timber Organization
KTH	Kelompok Tani Hutan
LCL	Local Community Leader
MAI	Mean Annual Increment
MoEF	Ministry of Environment and Forestry
MoEMR	Ministry of Energy and Mineral Resources
PHPL	Sustainable Production Forest Management
PMU	Project Management Unit
Sim	Simalungun
Tap	Tapanuli Selatan
TBS	Tandan Buah Segar
UHP	Usaha Hutan Produksi

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Summary

The specific objective of ITTO Project PD 737/14 Rev. 2 (I) was to improve enabling conditions for building up capacity to supply wood-based biomass energy in North Sumatera region; it was planned to be achieved through delivery of three outputs, one of which was “Development of sustainable supply of energy wood initiated”. In order to deliver this particular output, five activities were planned to be implemented, namely:

i. Activity 1.1 : To identify available suitable lands for development of energy forest in North Sumatera Province
ii. Activity 1.2 : To identify available suitable lands for development of energy forests on 3 FMUs in 3 districts (adjusted)
iii. Activity 1.3 : To establish energy forest models for purpose of demonstration and training
iv. Activity 1.4 : To provide estimates of sustainable supply potential of wood from energy forests established on degraded forest lands
v. Activity 1.5 : To assess long-term supply potential of energy wood from non-forest sources energy wood production.

All five project activities had been fully implemented and generated the outcomes that satisfied pre-defined indicators of Output 1 as highlighted below:

- Under Activity 1.1: Suitable lands for EFP development in North Sumatera region had been identified and mapped; the first indicator of the output was, therefore, met.
- Under Activity 1.2: suitable lands for growing gamal, kaliandra and lamtoro in three FMUs had been identified and mapped; hence, the second indicator of the output was met.
- Under Activity 1.3: gamal, kaliandra and lamtoro plantations had been established in Simalungun, Humbang Hasundutan and Tapanuli Selatan FMUs with a total area of 33 hectares or 92% of the target; therefore, the third indicator of the output was nearly satisfied.
- Under Activity 1.4: estimates of sustainable supply of planted energy wood have been developed; hence, the fourth indicator of the output had been met.
- Under Activity 1.5: potential supply of energy wood from non-forest sources had been assessed; the fifth indicator of the output had been, therefore, met.

As all planned activities under Output 1 had been fully implemented and results of the activities satisfied the pre-defined indicators of the output, it is justifiable to conclude that Output 1 had been delivered indeed.

1. Introduction

1.1. Background Information

ITTO Project PD 737/14 Rev.2 (I): “Developing Supply Capacity of Wood-Based Biomass Energy through Improved Enabling Conditions and Efficient Utilization of Degraded Forest Lands involving Local Communities in North Sumatra Province of Indonesia” had been implemented by Directorate of Production Forest Development (UHP) of Directorate General of Sustainable of Production Forest Management (PHPL) of the Ministry of Forestry (MoEF) of Indonesia in collaboration with the Indonesian Sawmill and Woodworking Association (ISWA) since October 2017 based on the project agreement duly signed by the Government of Indonesia (GoI) and The International Tropical Timber Organization (ITTO) in March 2017 and the Memorandum of Understanding on the implementation of the project duly signed by PHPL, the Executing Agency, and ISWA, the Collaborating Agency, on 18 September 2017.

The project was aimed at increasing contribution of the forest sector to renewable energy supply and regional economic development through increased supply of wood-based biomass energy. Its specific objective was to improve enabling conditions for building up capacity to supply wood-based biomass energy in North Sumatera region which was planned to be achieved through delivery of three outputs, namely:

i. Development of sustainable supply of energy wood initiated.
ii. Skillful manpower for development of wood-based biomass energy available.
iii. Investment in wood-based energy industry development promoted.

This report concerns with above-mentioned first output (Output 1) only, which was planned to be delivered through implementation of five activities, namely:

- Activity 1.1 : To identify available suitable lands for development of energy forest in North Sumatera Province.
- Activity 1.2 : To identify available suitable lands for development of energy forests on 3 FMUs in 3 districts (adjusted).
- Activity 1.3 : To establish energy forest models for purpose of demonstration and training

- Activity 1.4 : To provide estimates of sustainable supply potential of wood from energy forests established on degraded forest lands.
- Activity 1.5 : To assess long-term supply potential of energy wood from non-forest sources.

The project proponent hypothesized that the full implementation of above-listed five activities would deliver the first output as defined.

It is to be noted that this project was formulated in the first place by ISWA in response to the information on national energy market released by the Ministry of Energy and Mineral Resources (MoEMR) of Indonesia back in 2014 which revealed several serious problems, namely: i) the ever growing consumption of energy and sluggish development of supply capacity, ii) high dependence of supply on fossil energy, iii) growing government subsidy on energy overtime, iv) sub-optimal utilization of renewable energies and weak energy conservation program, and v) weak mitigation of climate change relating to energy production and consumption processes.

In its efforts to overcome the national energy problems, the MoEMR decided to implement policies on the supply side that focused on increasing renewable energy share in national energy mix from the current 7 percent to 23 percent in 2025. It was claimed by the government that the forest sector had a great potential to contribute to achieving the targeted share of renewable energy by utilizing available forest resources in a sustainable manner.

1.2. Organization of the Report

This report has been organized, to the extent possible, in accordance with existing ITTO Manual. The first part of the report provides background information on the project particularly on the objectives and deliverables. The second part elaborates on the methodologies applied in implementing individual activities pertaining to Output 1. The data collected or generated and outcomes of individual activities are presented in Part 3 while analysis and interpretation of data and results of the activities are described in Part 4. Conclusions and recommendations are presented in Part 5 while implication for practice is highlighted in Part 6 of the report.

2. Applied Methodologies

The output of the project planned for delivery was “development of sustainable supply of energy wood initiated”, by fully implementing five pertaining activities as listed previously. The methodologies employed in implementing individual activities are highlighted in the following sections.

2.1. Activity 1.1: To identify available suitable lands for development of energy forest in North Sumatera Province

The targeted outcomes

- Information on availability of lands suitable for energy forest plantation (EFP) development; and
- Map of lands suitable for growing gamal (*Gliricidia sepium*), kalliandra (*Calliandra calothyrsus*) and lamtoro (Leucaena leucocephala).

The executor

The activity was implemented with the assistance of Dr. Aswandi of Aek Nauli Forestry Research Institute (ANFRI) with the prior consent of the ITTO.

The operational strategy

As depicted in Figure 1, the operational strategy consisted mainly of data collection and data analysis tasks.

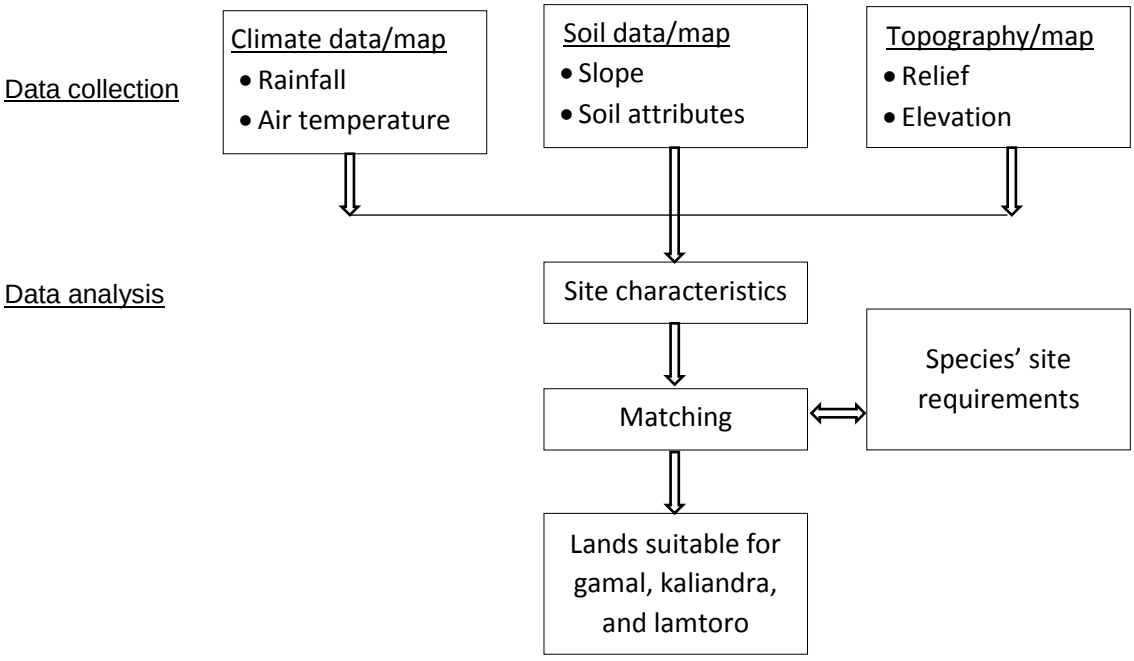


Figure 1: Employed operational strategy for land analysis at provincial level

2.2. Activity 1.2 To identify available suitable lands for development of energy forests on 3 FMUs in 3 districts (adjusted)

The targeted outcomes

- Map on suitable lands for EFP in three FMU samples; and
- Information on biophysical and socio-economic aspects of demo plantation sites in Simalungun, Humbang Hasundutan and Tapanuli Selatan FMUs.

The executor

The activity was implemented with the assistance of a competent ANFRI professional, Dr. Aswandi.

The operational strategy

The strategy or methodology employed was basically the same as that of Activity 1.1 but the scope of work was confined to the three FMUs where demo plantations, would be established.

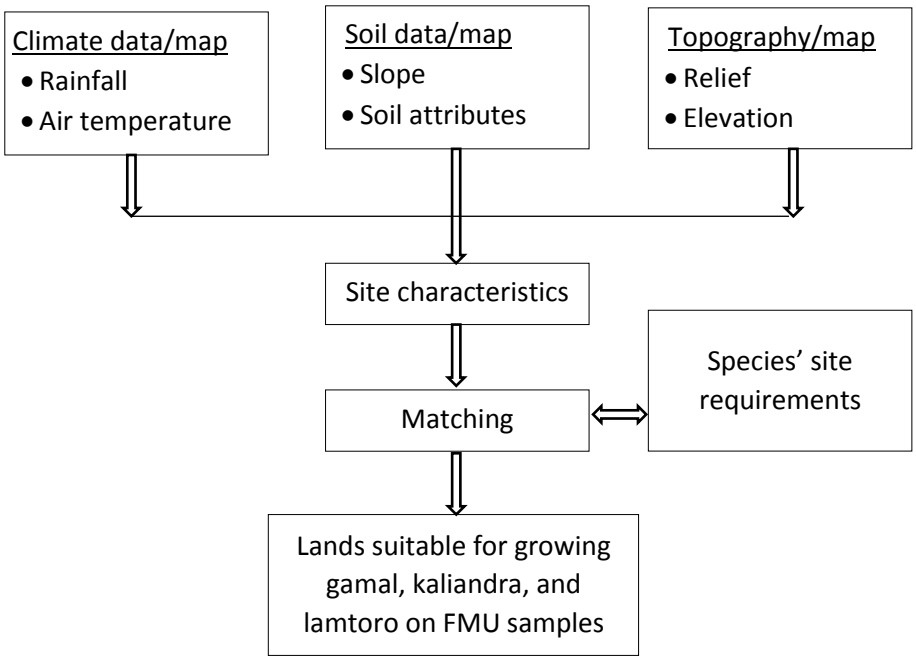


Figure 2. Employed operational strategy for land analysis at FMU level

2.3. Activity 1.3: To establish energy forest models for purpose of demonstration and training

The targeted outcomes

- 36 hectares of demo plantations using gamal, kaliandra and lamtoro species established at Simalungun (Sim), Humbang Hasundutan (Hum) and Tapanuli Selatan (Tap) FMUs;
- Data on growth and yield of grown tree species collected during the entire duration of the project;
- Maintenance of the species planted, comprising weeding, replanting, fertilizing, etc., continuously carried out during the project duration.

The executor

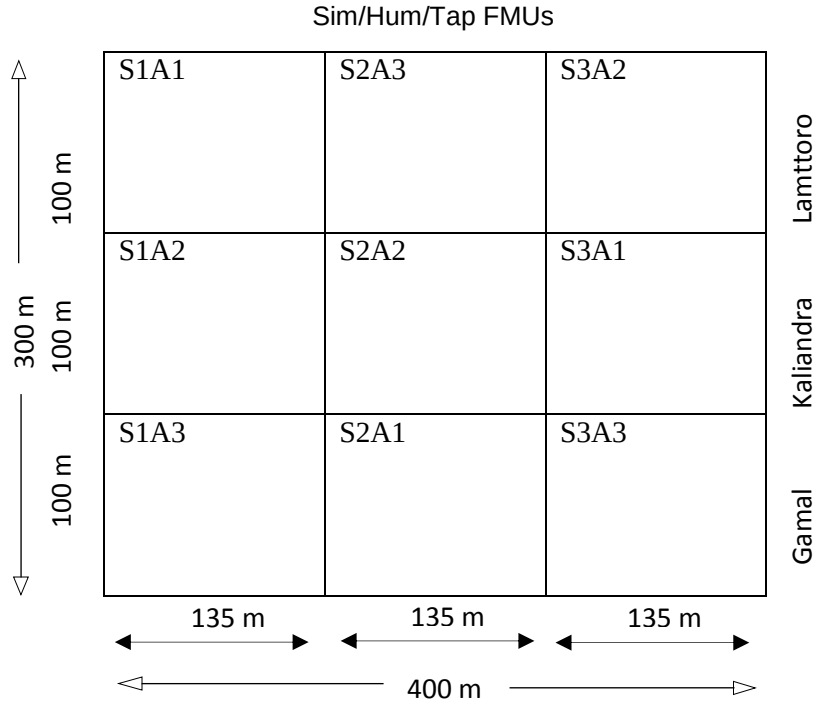
The activity was executed by the PMU in collaboration with local partners, notably competent scientists, local forest farmers groups (KTHs), FMUs, competent local contractors and local community leaders (LCL). Selected local contractors were CV Anggi and CV Rio.

The operational strategy

Major elements of the operational strategy employed are highlighted below:

- The PMU provided selected scientist with detailed information on expected outcomes of and available inputs to implementing the activity to be used as the basis for developing a sound design of demonstration plantations (demo plots);
- Selected scientist then developed a scientifically sound design of demo plots which was the application of a "factorial randomized block design" with two variables (spacing and age) and three replications (3 FMUs);
- The PMU solicited local contractors having capability of establishing the demo plots as designed; competent ones were appointed to establish demo plots based on detailed terms of reference developed by the PMU, with the prior expressed approval of the ITTO;
- A growth & yield monitoring plan was developed by the PMU, with the assistance of the ANFRI expert, as the basis for gathering data on growth and yield during the project duration for every four months starting August 2018;

- The PMU developed a maintenance schedule for the trees planted during the project duration, to be implemented with the assistance of local KTHs for every four months starting August 2018
- Applied design of the demo plantation is exhibited in Figure 3



- ✓ Spacing applied (S) : 1.5 x 1.0 m; 1.5 x 1.5 m; 1.5 x 2.0 m
- ✓ Harvesting schedule (A) : 24, 30 and 36 months
- ✓ Coppicing schedule : every 6 months after harvesting
- ✓ Replication : 3 FMUs

Figure 3. Factorial Randomized Block Design (FRBD)

2.4. Activity 1.4: To provide estimates of sustainable supply potential of wood from energy

The targeted outcomes

- Stand increment (height, diameter and biomass) of gamal, kaliandra and lamtoro calculated using growth data series obtained from the demo plantations established at 3 FMUs under Activity 1.3;
- Extent of available suitable lands on production forest areas in 13 districts identified and mapped;
- Estimates of sustainable supply of gamal, kaliandra and lamtoro in 13 districts, yet to be established on available suitable lands, derived using a growth & yield modeling process.

The executor

The activity was implemented with the assistance of a competent ANFRI professional, Dr. Aswandi.

The operational strategy

a. To develop growth & yield predictive models for gamal, kaliandra and lamtoro based on the growth data of the species collected from the demo plots at 3 FMUs;
b. To calculate rate of yield increment of individual species;
c. To identify available suitable lands for growing gamal, kaliandra and lamtoro on production forest lands in 13 districts;
d. To produce map of available suitable lands identified in c) above;

e. To provide estimates of sustainable supply of energy wood by species, harvestable from EFPs to be developed in 13 districts based on results of b) and c) above;
f. To identify enabling conditions for development of EFP in 13 districts using gamal, kaliandra and lamtoro;
g. To assess on optimal replacement ages of plantations of gamal, kaliandra and lamtoro under coppice silviculture system; i.e. how many years harvesting of coppices can be made before replacing the plantations;

2.5. Activity 1.5: To assess long-term supply potential of energy wood from non-forest sources

The targeted outcomes

Reliable information on:

- Non-forest sources of energy wood with respect to quantity and distribution;
- Long-term sustainable supply of each non-forest source, focussing on but not limited to palm oil and rubber plantations in North Sumatera province;
- Caloric attributes of the energy wood identified; and
- Feasibility of commercial use of energy wood identified taking collection cost into account.

The executor

The activity was implemented with the assistance of Dr. Aswandi of ANFRI based on proven competence in dealing with other activities of the project.

The operational strategy

- To identify non-forest sources of energy wood, focusing on but not limited to palm oil and rubber plantations;
- To estimate long-term sustainable supply of energy wood from each identified source;
- To collect information on caloric attributes of the energy wood from secondary sources;
- To assess feasibility of using the energy wood identified as the raw material for wood pellet industry to be constructed at Sei Mangkei or Gunung Tua site; and
- To verify accuracy of data on energy wood obtained from secondary sources through field surveys on randomly selected sites.

3. Presentation of Data and Findings

3.1. Available lands for EFP in 13 districts of North Sumatera.

a. Inside the production forest area
- In controlled production forest : 641,769 ha
- In permanent forest estate : 704,452 ha
- In convertible production forest : 75,684 ha

Total 1,421,905 ha

b. Inside the critical lands
- In Asahan-Barumun watershed area : 943,633 ha
- In Wampu-Ular watershed area : 310,501 ha

Total 1,254,134 ha

Grand total (a+b): 2,676,039 ha

c. Land suitability

Table 3.1: Suitability of available lands for growing energy wood species (Ha)

Suitability class	Gamal	Kaliandra	Lamtoro	Total
Very suitable	285,803	270,162	298,600	854,565
Moderately suitable	277,271	327,038	270,162	874,471
Marginally suitable	305,710	255,943	312,819	874,472
Not suitable for all	-	-	-	72,531
Total	868,784	853,143	881,581	2,676,039

3.2. Suitable lands for EFP in FMU samples

Table 3.2 Suitable lands for growing energy wood species (Ha)

FMU	Total area	Suitable lands
• Simalungun	33,739	7,823
• Humbang Hasundutan	78,941	11,812
• Tapanuli Selatan	73,253	12,419
Total	185,933	32,054

3.3. Performance of the demonstration plantations

a. Suitability of the sites for growing energy wood species

Table 3. Gamal's requirements vs site attributes

Element	Value	Forest Management Unit		
		Simalungun	Hum-has	Tap-Sel
Elevation	< 1,500	905 – 950 suitable	1,070 – 1,129 suitable	825 – 890 suitable
Rainfall (mm/a)	900 – 1,500			1,115 suitable
Soil type	Coastal, riverbanks, varying types, tolerates acid, and infertile soil	Red-yellow podzolic suitable	Red-yellow podzolic suitable	Red-yellow podzolic suitable
Light intensity (Lux)	Min 16 – 32,000	38 - 65,000 suitable	6,500 – 21,600 partly suitable	40 – 70,000 suitable
Daily air temperature (^{0}C)	20 – 29	19 – 32 partly suitable	16 – 27 partly suitable	21 – 31 suitable
Air humidity (%)	80 - 90	80 – 90 suitable	72 – 85 unsuitable	80 – 90 suitable

Land clearing at Simalungun and Humbang Hasundutan FMUs (Photos by PMU)

Conclusions:

Table 1 clearly indicates that Tapsel site was suitable for growing gamal; the site's attributes matched gamal's requirements to grow and develop. Simalungun site, however, was not fully suitable for growing gamal due to the too low minimum daily temperature. The Hum-Has site also did not fully match the required site conditions to grow gamal due to the too low light intensity that reached forest floor and the too low daily temperature.

Table 4. Kaliandra's requirements vs site attributes

Element	Value	Forest Management Unit		
		Simalungun	Hum-has	Tap-Sel
Elevation (masl)	800 – 1,860	905 – 950 suitable	1,070 – 1,129 suitable	825 – 890 suitable
Rainfall (mm/a)	1,000 – 4,000	suitable	3,156 suitable	1,115 suitable
Soil type	Different types: volcanic, alluvial, clay, etc.	Red-yellow podzolic suitable	Red-yellow podzolic suitable	Red-yellow podzolic suitable
Light intensity (Lux)	Min 16 – 32,000 Lux	38 - 65,000 suitable	6,500 – 21,600 partly suitable	40 – 70,000 suitable
Daily air temperature (^{0}C)	18 – 22	19 – 31.8 suitable	16 – 27 partly suitable	21 – 31 Suitable
Air humidity (%)	75 - 90	80 – 90 suitable	72 – 85 suitable	80 – 90 suitable

Land clearing at Humbang Hasundutan and Tapanuli Selatan FMUs (Photos by PMU)

Conclusions:

The information in Table 4 indicates that most of the kaliandra's requirements to grow up and develop were met by the sites except the light intensity and daily air temperature required by kaliandra to grow and develop were not fully met by the Hum-Has site.

Table 5. Lamtoro's requirements vs site attributes

Element	Value	Forest Management Unit		
		Simalungun	Hum-has	Tap-Sel
Elevation (masl)	< 1,000	905 – 950 suitable	1,070 – 1,129 less suitable	825 – 890 suitable
Rainfall (mm/a)	800 – 1,500	suitable	suitable	suitable
Soil type	Coastal, sandy soil types	Red-yellow podzolic suitable	Red-yellow podzolic suitable	Red-yellow podzolic suitable
Light intensity (Lux)	Min 16 – 32,000	38 - 65,000 suitable	6,500 – 21,600 partly suitable	40 – 70,000 suitable
Daily air temperature (^{0}C)	25 – 30	19 – 31.8 partly suitable	16 – 27 mostly not suitable	21 – 31 Suitable
Air humidity (%)	80 – 90	80 – 90 suitable	72 – 90 partly suitable	80 – 90 suitable

Survey location for gamal plantation at Simalungun FMU (Photos by PMU)

Conclusions:

Table 5 clearly indicates suitability of the site for growing lamtoro as follows:

- Overall, the attributes at Simalungun and Tap-Sel sites matched the requirements for lamtoro to grow and develop well
- The Hum-Has site only partly met the required light intensity and air humidity while required daily temperature was poorly met.

b. Survival rate of the wood species planted

Growth and development of the plantations were monitored since age 4 months for every 4 months till age 30 months; the survival rate of the species at different FMUs is as presented in Table 6.

Table 6. Survival rate of the species planted at different FMUs

FMUs	Species	Survival rate (%) at different ages (month)				
		4	12	20	24	30
Simalungun	Gamal	88.6	76.4	58.1	52.5	51.9
	Kaliandra	84.3	75.3	57.9	54.5	53.8
	Lamtoro	73.3	67.4	*	*	*
Hum-has	Gamal	77.9	74.3	*	*	*
	Kaliandra	74.2	71.9	*	*	*
	Lamtoro	72.1	69.4	*	*	*
Tap-Sel	Gamal	84.7	67.0	52.1	44.6	44.0
	Kaliandra	81.3	61.3	48.3	43.5	43.3
	Lamtoro	78.1	66.7	*	*	*
All FMUs	Gamal	83.8	55.6	55.6	48.6	48.0
	Kaliandra	79.9	53.1	53.1	49.0	48.5
	Lamtoro	74.5	67.8	*	*	*

**) species did not survive*

- At age 4 months, the overall survival rate of gamal was 83.8% which was quite high and comparable to the rate reached in Peru at 85% (in Aswandi, 2021). The rate drastically went down to only 48% at age 30 months.
- At age 4 months, the overall survival rate of kalindra was 79.9% which was much lower than the rate reached in Nusa Tenggara Barat at 84,89%; the rate went down drastically to 48.5% at the age of 30 months.

- At age 4 months, the overall survival rate of lamtoro was 74.5% and went down to 67.8% at the age of 12 months. Note that lamtoro did not survive till age 20 months at all planting sites.
- At Humbang Hasundutan FMU, all three species did not survive till age 20 months or died at the age less than 20 months. The high mortality rate of the species, in general was attributable to several factors including: i) prolonged dry season after planting, unsuitability of sites, high acidity of soil and low fertility. For kaliandra, while it is a pioneer species, it is a strongly intolerant species; kaliandra cannot stand shade nor compete with other species under a poor light environment.

c. Growth of the species planted

Height increment of gamal, kaliandra and lamtoro is exhibited in Table 7 while diameter increment is shown in Table 8.

Table 7. Height growth by species and different ages

Species	Element	Height growth at different ages (months)						
		4	8	12	16	20	24	30
Gamal	Height	40.4	44.0	51.7	110.5	166.5	210.5	275.2
	CAI [1)]		3.6	7.7	58..8	56.0	44.0	64.7
	MAI [2)]	121.3	66.0	51.7	82.9	99.9	105.3	110.1
Kaliandra	Height	25.1	28.4	44.3	122.7	192.5	250.0	305.0
	CAI		3.3	15.9	78.3	69.8	57.5	55.0
	MAI	75.3	42.7	44.3	92.0	115.5	125.0	122.0
Lamtoro	Height	23.2	24.1	26.7				
	CAI		0.9	2.6				
	MAI	69.7	36.2	26.7				

1) CAI (current annual increment) is growth rate between two consecutive years
2) MAI (mean annual increment) is annual growth during the entire age considered

Table 8. Diameter growth by species and different ages

Species	Element	Height growth at different ages (months)						
		4	8	12	16	20	24	30
Gamal	Diameter	1.8	1.9	2.2	3.8	4.8	5.3	5.9
	CAI	1.8	0.1	0.3	1.6	1.0	0.5	0.6
	MAI	5.4	2.9	2.2	2.9	2.9	2.7	2.3
Kaliandra	Diameter	0.29	0.3	0.5	2.2	3.0	4.3	5.8
	CAI	0.3	0.01	0.2	1.7	0.8	1.4	1.5
	MAI	0.9	0.5	0.5	1.7	1.8	2.2	2.3
Lamtoro	Diameter	0.3	0.3	0.3				
	CAI	0.3	0.0	0.0				
	MAI	0.3	0.5	0.3				

d. Yield of planted energy wood

Yield of planted energy wood was recorded only for gamal and kaliandra species as lamtoro grew poorly at all sites after aging 20 months whilst harvest was only started at age 24 months. Yield of gamal and kaliandra was recorded at 3 different ages: 24, 30 and 36 months on 3 different spacing: 1.5 x 1.0 m; 1.5 x 1.5 m and 1.5 x 2.0 meter. For each species and spacing, 4 experimental harvest plots were constructed, each assigned with specific harvest schedule as follows:

- Plot 1: harvesting at age 24 months, coppicing at ages 30 and 36 months
- Plot 2: harvesting at age 30 months, coppicing at age 36 months
- Plot 3: harvesting at age 24 months, coppicing at age 36 months
- Plot 4: harvesting at age 36 months

Gamal and kaliandra plantation at Simalungun FMU (Photos by PMU)

Total yield between the plots with the same spacing was then compared to arrive at the best harvesting schedule. Yield data are presented in Table 9. Please note that harvesting refers to the original cutting of the trees while coppicing refers to cutting of the shoots originating from the cut trees.

Figures in Table 9 indicate some interesting findings as highlighted below:

i. Yields of energy wood were consistently largest on 1.5 x 1.0 spacing compared to other spacing at all harvest schedules; this is true for both gamal and kaliandra. More densed spacing yielded larger volume of wood than the less densed ones.

ii. For both gamal and kaliandra, for the same spacing, original harvest only yielded less volume of wood compared to all other harvest schedules.

iii. For gamal, for the same spacing, original harvest volume at age 24 months was larger than the first or second coppice harvest but smaller than the first and second coppice harvest together indicating the fact that it was worth waiting for one more year and made two coppice harvests to yield 24.18 tonnes compared to 13.65 tonnes of original harvest at 24 months.

Gamal and kaliandra plantations at Tapanuli Selatan FMU (Photos by PMU)

Table 9. Yield of gamal and kaliandra at different ages and harvest schedule (ton/ha)

Age	Gamal				Kaliandra			
Spacing	Plot 1	Plot 2	Plot 3	Plot 4	Plot 1	Plot 2	Plot 3	Plot 4
24 months								
1.5 x 1.0 m	13.65	-	13.26	-	16.09	-	15.60	-
1.5 x 1.5 m	9.45 c	-	9.71 c	-	10.94 c	-	10.94 c	-
1.5 x 2.0 m	6.68 c	-	6.90 c	-	7.60	-	7.35	-
30 months								
1.5 x 1.0 m	11.31 c	14.43 h	-	-	20.48	21.45	-	-
1.5 x 1.5 m	8.14 c	9.98 c	-	-	13.75	14.38	-	-
1.5 x 2.0 m	6.45 c	7.12 c	-	-	8.09	9.80	-	-
36 months								
1.5 x 1.0 m	12.87 c	19.11 c	17.16 c	22.62 h	22.91	23.89	24.86	32.66
1.5 x 1.5 m	11.55 c	11.55 c	12.86 c	17.32 h	15.94	17.19	18.75	25.31
1.5 x 2.0 m	7.57 c	8.90 c	11.35 c	15.35 h	9.56	10.78	12.50	15.19
Total yield at Age 36 months								
1.5 x 1.0 m	37.87	33.54	30.42	22.62	59.48	45.34	40.46	32.66
1.5 x 1.5 m	29.14	21.53	22.57	17.32	40.63	31.57	29.69	25.31
1.5 x 2.0 m	20.70	16.02	18.25	15.35	22.25	20.58	19.85	15.19

iv. Overall, kaliandra yielded larger volume of wood than gamal obtained from both original and coppice harvest indicating the fact that, *ceteris paribus*, growing kaliandra is preferable to gamal to produce energy wood.

v. Overall for both gamal and kaliandra, spacing 1.5 x 1.0 meter yielded largest volume of wood compared to other spacing.

vi. The best harvest schedule in term of energy wood yield was to do original harvest at age 24 months and make two consecutive coppice harvests till age 36 months with a six-month interval.

vii. Under the most preferred spacing (1.5 x 1.0 meter) and best harvest schedule, gamal yielded a total of 37.87 tonnes of energy wood at age 36 months compared to 59.48 tonnes for kaliandra which is amounting to say that the mean annual increment (MAI) of gamal was around 18 m^3/Ha/y and 28.32 m^3/Ha/y for kaliandra.

3.4. Estimates of sustainable supply of EFP

It was indicated in Section 3.3 (d) that, based on actual harvest yield, the MAIs of gamal and kaliandra were 13 tonnes/Ha and 20 tonnes/Ha, respectively. The yield figures obtained through direct field measuring were somewhat different from the yield figures obtained by the predictive growth model developed by the National Consultant under Activity 1.4 which were 6

tonnes/Ha for gamal, and 12.5 tonnes/Ha for kaliandra. This difference in MAI figures between actual (field measure) and conceptual is not surprising. Estimates of biomass increment produced by the growth model are presented in Table 10.

Table 10. Biomass of energy wood by species at different ages

Species	Elements	Unit	Age (Year)				
			1	2	3	4	5
Gamal	Diameter	Cm	1.9	3.6	6.9	13.1	24.8
	Density	N/ha	3,328	2,493	1,867	1,399	1,048
	Biomass	Ton/ha	1.13	4.51	18.06	72.36	289.89
	Increment	Ton/ha/year	1.13	2.25	6.02	18.09	57.98
Kaliandra	Diameter	Cm	1.1	4.0	8.6	14.90	22.90
	Density	N/ha	3,182	2,545	1,892	1,459	1,125
	Biomass	Ton/ha	0.26	6.48	37.53	122.20	290.15
	Increment	Ton/ha/year	0.26	3.24	12.51	30.55	58.03

3.5. Potential supply of energy wood from non-forest sources

a. Palm oil plantations

- The extent of plantations in North Sumatera in 2019 reached 1.26 M hectares, which spreaded throughout the eastern, southern and western parts of the region, managed as small-scale plantations by local communities app. 34%, in large-scales by state owned companies and private sector app 23% and 43%, respectively;
- The total replanting area of palm oil in 2020 was around 14,500 hectares with a total biomass potential of around 2.249 M tonnes;
- As regards potential supply of palm oil biomass to planned wood pellet industry at Sei Mangkei, around 930,656 tonnes could be sourced every year from Simalungun, Asahan and Serdang Bedagai districts while for the industry at Gunung Tua, a total supply of 1.086 M tonnes/a could be obtained from six nearby districts;
- On average, the palm oil plantation produce 11.7 M tonnes/year of fresh fruit bunches (TBS). One ton of TBS could produce: 65 kg (6.5%) of shells with an energy potential of 4,105 kcal/kg, 130 kg of fibres (13%) of fibres with an energy potential of 2,637 kcal/kg, and 230 kg (23%) of empty fruit bunches which is equivalent to 4,492 kcal/kg of energy.


Palm oil plantations in Simalungun district (Photos by PMU)

b. Rubber plantations

- In 2020, the total of rubber plantations in North Sumatera region was around 430,812 hectares with a total replanting area of app. 16,719 hectares which could produce around 3,750 M tonnes/a of wood biomass that can be used to produce different forms of energy;
- If the rubber wood biomass was converted to energy, potential supply could reach 13,784 B kcal/a assuming that the average energy content of rubber wood is around 4,000 kcal/kg of biomass.


Rubber plantation in Simalungun district (Photos by PMU)

c. Other sources of wood biomass

The research identified different non-forest sources of wood biomass as summarized in Table 11

Table 11. Estimates of wood biomass and energy potential supply of estate plantation in North Sumatera

No.	Species	Total area (Ha)	Replanting area (Ha)	Wood biomass (ton)	Energy potential (M kcal)
1	Coconut	103,675	3,456	525,849	2,434,680
2	Robusta coffee	19,809	990	55,424	217,984
3	Arabica coffee	67,403	3,370	86,437	339,958
4	Cocoa	60,499	3,025	164,827	659,308
5	Clove	3,289	110	1,605	6,741
6	Styrax	22,949	459	97	341
7	Cinnamon	5,801	232	34	164
8	Aleuritis	10,994	440	85	297
9	Arenga	6,272	251	16	41
10	Tea	4,102	103	15,477	74,738

Source: Aswandi, 2020

4. Discussions

4.1. Assessing Performance of the Demonstration Plantations

Overall, all three species planted did not perform well; three factors had been identified as affecting performance of the species as highlighted below:

i. Site suitability

- Light intensity and micro-climate at Hum demo plantation were not suitable for growing gamal and kaliandra as the minimum required light intensity was not met due to insufficient clearing of vegetation;
- Micro climate, altitude and minimum light intensity requirements for growing lamtoro were not met at all three sites resulting in the very low survival rate of the species after and beyond twenty months of age.

ii. Soil attributes and fertility

- The acid and low fertility of soil at all sites had adversely affected early growth of lamtoro which resulted in the poor growth and development during the subsequent stages;
- While gamal and kaliandra could survive better than lamtoro, these species also did not perform satisfactorily.

iii. Planting operation techniques

- At Hum demo site, land preparation and clearing of vegetation did not provide sufficient light intensity to support normal growth of all species planted. In addition, planting holes were too shallow for young plants to reach mineral soil due to the thick litter that covers the forest floor.
- Appropriate planting techniques for each species were not applied which made planted materials or seedlings stressful at all sites;
- The planting materials of gamal and lamtoro used, did not meet the standards at all sites: irregular dimension of gamal stumps obtained from young branches were used; too small size (20-35 cm) of lamtoro planting materials made the species not strong enough to survive on acid and poor soil nor to complete with weeds;

- At Tap demo site, late weeding was carried out that weeds had dominated growth of all species; fertilization after weeding could not promote growth of the species fast and strong enough to beat the weeds.

In conclusion, the poor performance of demonstration plantations was attributable to poor site suitability to grow the species due to poor exercise of species-site matching, which was aggravated by low fertility of soils and use of inappropriate planting techniques.

4.2. Growth and Yield of Demonstration Plantations

- As shown in Table 6, the survival rate of the energy species planted were, overall low at all FMUs. By age 30 months, for instance, the survival rates of gamal were only 51.9% and 44.0% at Simalungun and Tapanuli Selatan FMUs, respectively; the survival rate figures for kaliandra were 53.8% and 43.3%.
- In fact, all three species did not survive until age 20 months at Humhas FMU, while lamtoro did not survive until 20 months at all three FMUs. This case was surprising indeed as the survival rate of the species planted on other sites in Indonesia and abroad was much higher.
- Causes of the low survival rate were believed to include the prolonged dry season after planting, unsuitability of the sites for the species chosen, the acid and infertile soils as well as poor technical skills of the farmers involved in various stages of plantation establishment. Recall that farmers had only received such technical trainings by the second year of project operations.
- It is worth noting that, despite the fast growing attribute of kaliandra, the species is positively intolerant of shading, it requires sufficient sunlight. The lamtoro plantation at Humhas FMU clearly illustrates the intolerance of the species to shading. Most of intolerant species require at least 40% of full sunlight to grow and develop or around 16 – 32,000 lux. At Humhas demo site, the light intensity that reached the forest floor was only 6,500 – 21,600 lux which is obviously less than the light required by gamal, kaliandra and lamtoro to grow and develop optimally.
- As regards kaliandra, it can grow well at a minimum temperature of 18 – 22^0C, and it is proned to frozen environment. The Consultant found that the average daily temperature at Humhas demo site was 16 – 27^0C which was somewhat too low for gamal, kaliandra and lamtoro to grow and develop normally. In addition, the relative humidity at 72 – 85% at altitude 1,070 – 1,129 meter asl. could facilitate air freezing process in the night which might have adversely affected survival rate of the species.
- Lamtoro grows well at the site with average daily temperature of 25 – 30^0C at altitude less than 1,000 meter. At higher elevation, lamtoro does not grow well; at lower temperature, e.g. 15 – 16^0C lamtoro would cease to grow. The investigation conducted by the project consultant indicated that the elevation and daily temperature of the Humhas site did not match the requirements of lamtoro.
- The low survival rate was followed by the unsatisfactory growth in terms of height and diameter of the species as shown in Tables 7 and 8. The height MAIs of gamal and kaliandra at age of 30 months were 110 cm and 122 cm per year, respectively; which were much lower than the MAIs recorded in South America (in Aswandi 2021).
- Overall, similar to survival rate and height growth, growth of diameters of all species was also found as lower than the growth observed in South America. Data in Table 8 indicates that the MAI of diameter for gamal and kaliandra was the same at 2.3 cm/year which was lower than the figures documented in South America.
- The causing factors of the low growth of height and diameter of the species planted were unsuitable sites, marginal attributes of the soils used and poor technical skills for planting as well as for maintenance of plantations.

- A number of weaknesses on technical aspect of demo plantations development were also observed as highlighted below:
  i. On different part of the demo sites, litter was thick; the planting holes were not deep enough to reach the mineral soil. As the results, the rooting system was unable to obtain sufficient water and nutrients from mineral soil, especially after the very early stage of planting. Note that during the first months, perhaps up to three months, the nutrient is available from the planting media kept in the polybag; soon after the nutrient is finished, the planted materials would be suffering of nutrient gap and adversely affecting growth.
  ii. The planting material of gamal used was in the form of stump; it was found that the quality of the stumps used were irregular or inferior as some stumps were too young, too small or too short resulting in poor growth and survival.
  iii. As regards lamtoro planting, the seedlings planted were too young and small to survive the environment including the acid soil, low temperature and insufficient light intensity and resulted in low survival rate and poor growth.
  iv. The late maintenance of young plantations was also another factor that contributed to the performance of plantations. At all demo sites, the late maintenance works were carried out, resulted in weeds growing faster than the plantations causing suppressed growth or mortality of plantations.

Above discussion revealed that several ecological and technical forces had contributed to the unsatisfactory performance of the demonstration plantations as reflected in the survival rate of all species as well as the inferior growth of height, diameter and yield.

4.3. Delivery of Planned Output

The first output of the project (Output 1) planned for delivery was defined as “Development of sustainable supply of energy wood initiated“. Proponent of the project conceptualized that this output would be delivered if all of the planned activities have been fully implemented based on the notion that planned activities had been defined in conformity to the sub-causes of the first main problem to be resolved through delivery of Output 1. In other words, delivery of Output 1 is conditional to realization of planned activities as examined below.

Activity 1.1: To identify available suitable lands for development of energy forest in North Sumatera Province

- The activity had been fully realized with the assistance of a competent expert of ANFRI; suitable lands for EFP in North Sumatera region had been identified and mapped using scientifically sound methodology.
- A technical report on the implementation of the activity had been submitted to the project by the expert in charge.

Activity 1.2: To identify available suitable lands for development of energy forests on 3 FMUs in 3 districts (adjusted)

- The activity (modified with PC’s consent) had been fully implemented with the assistance of a competent expert of ANFRI;
- Available suitable lands for EFP in three FMU samples were identified and mapped using a sound methodology;
- Available suitable lands for sites of demonstration plantations had been identified in collaboration with local communities;
- A technical report on the implementation of the activity had been submitted to the project by the expert in charge.

Activity 1.3: To establish energy forest models for purpose of demonstration and training

- The activity had been fully realized with the assistance of small local firms using a sound methodology developed by a competent scientist; demo plantations were established under a Factorial Randomized Block Design (FRBD);
- Out of 36 hectares of planned plantations, 33 hectares or 92% had been realized using gamal, kalliandra and lamtoro;
- Growth and yield of the demo plantations were monitored continuously at the three sites and data collected well documented;
- A technical report on the execution of the activity was prepared by the executors and well received by the project.

Activity 1.4: To provide estimates of sustainable supply potential of wood from energy forests established on degraded forest lands

- The activity had been fully implemented with the assistance of a competent expert of ANFRI;
- The methodology employed was scientifically sound and the implementation process was consistent with the terms of reference developed by the PMU;
- Targeted outcome of the activity, i.e. estimates of sustainable supply of energy wood planted on degraded lands, available;
- A technical report on the implementation of the activity had been submitted to the project by the expert in charge

Activity 1.5: To assess long-term supply potential of energy wood from non-forest sources energy wood production

- The activity had been fully realized with the assistance of a competent expert of ANFRI;
- The methodology employed was sound, the implementation process was consistent with the TOR and planned outcomes were produced, i.e. potential supply of energy wood from non-forest sources, assessed.
- Detailed outcomes of the activity were presented in Section 3.5;
- A technical report on the implementation of the activity had been submitted to the project by the expert in charge.

Conclusion

- As all planned activities under Output 1 had been fully implemented, the output must have been delivered. This conclusion was confirmed or otherwise by matching indicators of Output 1 achievement with the outcomes of implemented activities as follows:
  Indicator 1: Available suitable lands for energy forest development identified and mapped.
  - ✓ This indicator was satisfied through Activity 1.1;

  Indicator 2: Available suitable lands for EFP on 3 FMUs identified and mapped.
  - ✓ This indicator was satisfied through Activity 1.2;

  Indicator 3: 36 ha of energy forests established at 3 FMUs using 3 species.
  - ✓ The indicator was 92% met under Activity 1.3;

  Indicator 4: Estimates of sustainable supply of energy wood planted on degraded lands available.
  - ✓ The indicator was satisfied through Activity 1.4; and

  Indicator 5: Potential supply of energy wood from non-forest sources assessed.
  - ✓ The indicator was satisfied through Activity 1.5.

- As all defined indicators of Output 1 had been satisfied, noting that indicator #3 was met only 92%, it was justifiable to confirm delivery of Output 1.

5. Conclusions and Recommendations

5.1. Conclusions

a. The extent of available suitable lands for EFP development in 13 districts of North Sumatera province was 2.68 M hectares in total, situated 1.42 M hectares inside the production forest areas and 1.26 M hectares inside the critical land areas

b. The extent of suitable lands for EFP development in FMU samples was 32,054 hectares in total: 7,823 hectares in Simalungun FMU; 11,812 hectares in Hum-Has FMU and 12,419 hectares in Tapanuli Selatan FMU.

c. Close examination of the species-site matching indicated that:
   i. The Humbang-Hasundutan site was not fully suitable for growing gamal due mainly to insufficient light intensity, too low daily temperature as well as humidity. For the same reasons, the site was also not fully suitable for growing kaliandra and lamtoro;
   ii. The Simalungun site was generally suitable for growing gamal and lamtoro except the daily temperature which was somewhat too low. The site was fully suitable for growing kaliandra;
   iii. The Tapanuli Selatan site attributes were found fully suitable for growing gamal, kaliandra and lamtoro.

d. Overall, the survival rate of all three species planted were low compared to other planting sites. At the age of four months the rate was somewhat normal, ranging from 84% for gamal, 80% for kaliandra and 75% for lamtoro. However, the survival rates went down drastically as the age reached 12 months.

e. All three species did not survive until age of 20 months at Hum-Has site while lamtoro did not survive until 20 months at all three FMUs.

f. Overall, all three species planted did not perform well in terms of survival rate, growth (of height and diameter) and yield. The poor performance was attributable to both ecological and technical factors.

g. At 4 years of age, the MAIs of gamal and kaliandra were app. 18 tonnes/ha/year and 31 tonnes/ha/year, respectively.

h. The total replanting area of palm oil in 2020 was around 14,500 hectares with biomass potential of around 2.249 M tonnes; the total replanting area of rubber was 16.719 hectares in 2020 which could produce around 3.75 M tonnes of biomass.

i. All five planned project activities had been fully implemented and produced the expected outcomes that met predefined indicators of Output 1. Hence, by hypothesis, Output 1 “development of sustainable supply of energy wood initiated” had been delivered, noting that the extent of the demonstration plantations established was only 33 hectares in total or 3 hectares short of the target, i.e. 36 hectares.

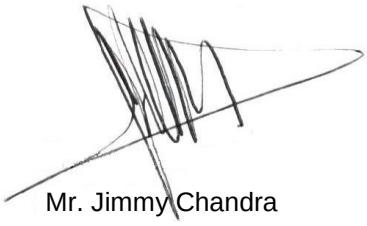
5.2. Recommendations

a. In energy forest plantation development, it is strongly recommended to perform an in depth species-site matching analysis to ensure a satisfactory growth and development of the species chosen to develop.
b. In addition to performance an adequate species-site matching process, technical aspect of the actions involved must be handled with care which include treatment of planting site, production and handling of planting materials and maintenance of young plantations.
c. Using inferior planting materials due to insufficient size of stump or age of seedling must be avoided as it entails risks of poor growth and development, and consequently poor yield of the species planted.
d. To ensure that technical aspect of energy forest plantation development is adequately taken care of, conducting a training program on needed technical skills is strongly recommended prior to embarking in development operations.
e. In identifying lands for demonstration site, accessibility of the site must be placed as the top criterion for site selection to facilitate optimal use of the site and monitoring of the plantations, in tandem with site suitability for growing desired three species.

6. Implication for Practice

- Failing to perform a thorough species-site matching analysis may result in big loss due to poor growth and yield of growing a tree species on a site that does not meet the requirements of the species to grow and develop optimally.
- The supply potential of energy wood from rubber plantation is huge but using the wood for producing energy may not compete with furniture industry that using wood wastes of furniture manufacturing is economically more justifiable than using the original rubber energy wood.

Responsible for the report

Project Coordinator	Management Advisor
	
Mr. Jimmy Chandra	Dr. Hiras Sidabutar

Date: November 2021

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