Research Journal of Applied Sciences 8 (4): 252-261, 2013
ISSN: 1815-932X

Is Parawood Environmental Friendly Material? What should Be Known Before Answer?

Phairat Usubharatana, Harnpon Phungrussami and Nicha Sukhodomchot
Excellent Centre of Eco-Energy (ECEE), Faculty of Engineering,
Thammasat University, Bangkok, Thailand

Abstract: Since, Parawood is claimed to be an environmental friendly material, this review aims toreveal the environmental aspects of Parawood for Life Cycle Inventory (LCI) preparation. The scope of this review includes both quantity and quality of goods, substances and energy that are factors of production of Parawood products supply chain of which the boundary of this literature review includes land-used change, cultivation period, rubber harvesting and maintaining growth, felling, sawing, wood preservation, kiln drying, finger joint and lamination. From this literature review, it is shown that many data is needed to bring in to complete the inventory. Even Parawood is by-product of a tree plantation crop (rubber) and is concurred as sustainable material, there are still many disadvantages. To make Parawood to be environmentally friendly and truly sustainable products, limitations and other impacts need to take into account. Life Cycle Impact Assessments (LCIA) of interested characteristics (for instance global warming potential, acidification, ozone layer depletion, etc.) are required subsequent to LCI data.

Key words: Parawood, environment management, LCI, LCIA, account

INTRODUCTION

Thailand's forests suffered major deforestation between the 1960s and 1980s. The peak was in the 1970s when the annual loss was about 500,000 h or approximately 2.5% of the total forest area. There were two major reasons for this: increasing demand for agricultural land as well as commercial loggings. Other reasons have been road construction use for other infrastructure and tourism. After logging was banned in 1989 (declared after a devastating flood in 1988) to protect Thailand's remaining natural forests, the wood-based industries were forced to move to other raw-material sources. Importing timber from neighboring countries is also restricted for Thailand. The only solution to fulfill the demand is combination of the sustainable management of natural forests and efficient wood production from forest plantations or agricultural by product, Parawood for instance (Niskanen and Saastomoinen, 1996).

Parawood's importance as a raw material for sawmills in South East Asia has increased including Thailand. It has already replaced natural wood as raw material for various end products because of its properties. The Para-rubber tree (*Hevea brasiliensis*) was first introduced in Southern Thailand in 1900. Rubber planting has been actively promoted by the government since the 1960s and the total area reached 2.86 million h in 2010 (Agriculture fundamental data of Thailand by 2010) Rubber wood's rotation period is about 25-30 years when the production of latex is uneconomical the trees are fallen for replanting. Earlier the felled trees were of low commercial value and were mainly used as fuelwood.

The emergence of Parawood as an internationally established wood product has often been termed an environmentally friendly wood. This is especially important for product exported to European and Japanese who are becoming more and more environmentally conscious. Various factors have contributed to this development, first, the fact that Parawood represents a relatively sustainable alternative to tropical woods extracted from natural forests as a by product of a tree plantation crop (rubber). Furthermore, Parawood's pale whitish color is one of the principal reasons for its popularity. It takes finishes and stains easily. The wood is soft to moderately hard and the air-dry density is between 560-640 kg/m^3. Moreover, Parawood has good overall machining and wood working qualities for sawing, boring, turning, nailing and gluing.

Thailand is now one of the world's leaders in Parawood furniture exports (ITTO, 2006). In 2003 total

Corresponding Author: Phairat Usubharatana, Excellent Centre of Eco-Energy (ECEE), Faculty of Engineering, Thammasat University, Bangkok, Thailand

export value of kiln dry rough sawn Parawood and products of them is 47,393 million THB (Thai Baht: 30 THB≈1 USD). This value had increased 3 to almost 100,000 million THB in year 2008 which around 70% of this value is from various kind of finish furniture and components. Those exclude the domestic use which has the estimated value of 20,000 million THB a year. In Thailand, potential sawlog and sawn wood availability is projected to increase from 2.8-4.18 million m^3 and 0.84-1.25 million m^3 from 1997-2012, respectively.

On the other hand, the disadvantages which retard environmental aspect are also evident in Parawood. First, the lumber recovery is low it is about 15-35% in small sawmill and the average lumber recovery is about 25%. Moreover, its fast biodegradation and susceptibility to insect infestations after felling, Parawood logs must be sawn as soon as possible and preservation with chemical. Then, kiln dry process after preservation, consumed massive energy is required. Finally, kiln dry rough sawn Parawood is not well-liked to use as final product. Further products as wood joint and laminated wood processing tend to increase energy consumption and additional waste.

SYSTEM BOUNDARY AND FLOW DIAGRAM

The Cradle to Gate Life Cycle Models presented in Fig. 1 are an integration of gate-to-gate procedure including cultivation, maintenance, falling, transportation, mill saw, preservation, kiln drying, finger joint and laminating. In the boundary of this life cycle give ten cradle to gate a ssessments for the eight products: para-rubber, wood logs, twig and branch, lumber, slab, sawdust, kiln dried lumber and laminated wood. In each step of cradle to gate life cycle, product from earlier process is used as raw material. Production's factors are also provided as input material. List of input materials shown in Fig. 1 are only significant environmental impact material normally found in that process. Energy and natural resources are consumed in both production factor sand some processes, themselves. Consumption of energy and natural resources in process and also in their input material process cause emission and pollution problems such as air pollution and hazardous waste. CO_2 stock of Para-rubber tree plantation is considerable aspect which this industrialgrant to environment.

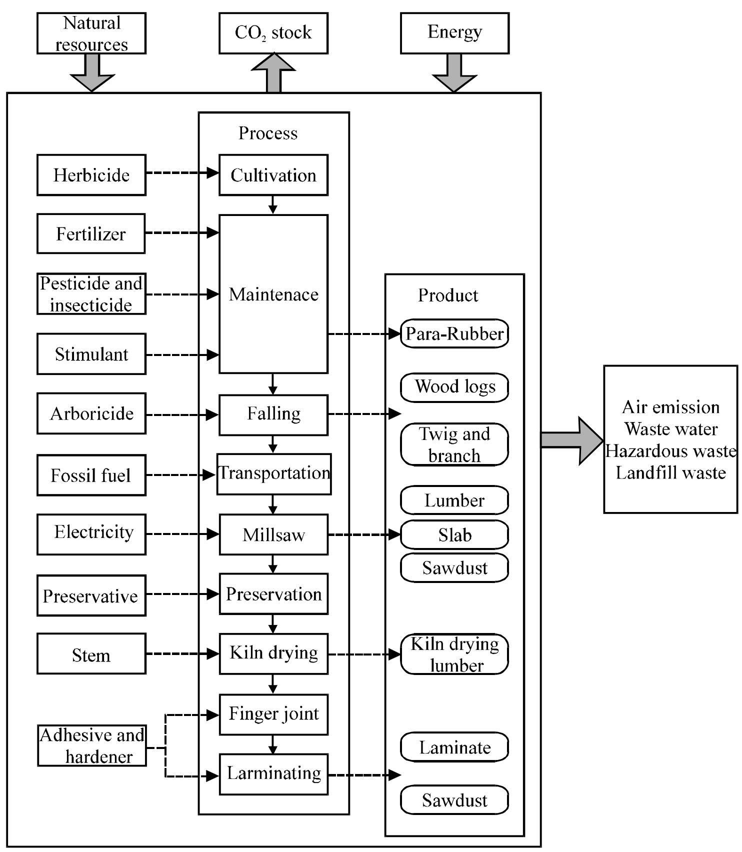

Fig. 1: Boundary of study

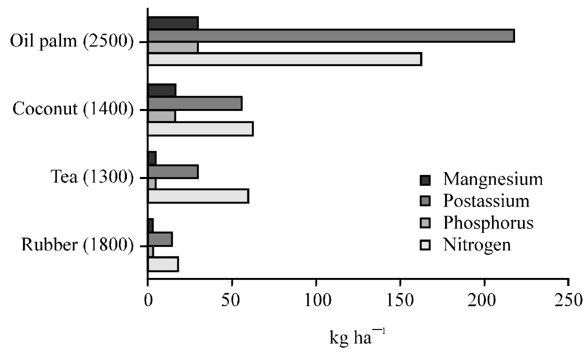

Fig. 2: Nutrient removal and yield of different crops (Sethuraj *et al*., 1989)

CULTIVATION

In environmental management science is important to take into account that land selected for planting must be ecologically and economically. There is little doubt that Parawood relieves pressureon remaining forest areas however, agro-forestry researchers are also paying increasing attention tothe role of smallholder cultivation as an alternative to certain types of unsustainable food crop-basedshifting cultivation systems (Balsiger *et al*., 2000). Rubber cultivation transform from shifting cultivation to a more permanent settled form of agriculture which has been recognized as a best bet land use system for the humid tropics, nevertheless local and global impacts are both considered (Van Noordwijk *et al*., 1995; Tomich *et al*., 2000). Soil degradation has been identified as one of the negative effects brought by plantations. It is evidently to stress that fast-wood plantations aregenerally much less degrading the soil than many commercial agricultural crops as shown in Fig. 2 which parentheses behind crop names indicate yield kg/ha. Research on soils degraded in Northeast India has demonstrated an improvement of soil properties such as bulk density, soil porosity, moisture retention and infiltration in rubber plant area (Krishnakumar *et al*., 1990).

CARBON STOCK

Carbon sequestration is a good alternative for tackling global warming. The idea is mainly touse plantation to lock up carbon in living trees and then after timber is harvested, the carbon will betransferred into durable constructions and furniture. Physiological studies have shown that rubber treeis more effective than teak grown in plantation conditions in taking up carbon dioxide (Sethuraj and Jakob, 1977). Cultivation of rubber trees on non-forested land could act as a carbon sink by sequestering carbon in biomass and indirectly in soils by following the context of afforestation and reforestation activity (Wauters *et al*., 2008). Studies were carried out on carbon sequestration inrubber tree plantations (Yang *et al*., 2005). Many studies estimate above ground biomass (Chaudhuri *et al*., 1995; Dey *et al*., 1996; Rodrigo *et al*., 2005; Rojo-Martinez *et al*., 2005; Schroth *et al*., 2002; Shorrocks *et al*., 1965). Many other studies examined soil organic carbon evolution in rubber fields (Aweto, 1995; Karthikakuttyamma *et al*., 1998; Mandal *et al*., 2001; Yang *et al*., 2004; Zhang and Zhang, 2003, 2005). Some information such as understorey vegetation and litter were rarely investigated (Philip *et al*., 2003; Ren *et al*., 1999). Investigation of changing in carbon stock with stand age including all the carbon pools were also conducted (Wauters *et al*., 2008). Actually, the rate of biomass production depends on photosynthesis capability per leaf area and overall leaf area per tree which vary by tree species. In high intensity sun light, mature leaf of rubber tree can consume CO_2 at rate 10-15 μ/mole/m^{2}sec compare to range of 5-13 μ/mole/m^{2}sec of other photosynthetic plant (Sethuraj and Jakob, 1977). By 2050, the area of land dedicated to rubberand other diversified farming systems could more than double or triple, largely by replacing landsnow occupied by evergreen broadleaf trees and swidden-related secondary vegetation. The conversion of both primary and secondary forests to rubber threatens biodiversity and may result in reduced total carbon biomass (Li *et al*., 2007, 2008; Qiu, 2009).

IRRIGATION

A high production of timber material usually requires a large amount of water. To maintain 12-24 dm of fresh latex from one rubber tree per year it is necessary to supply 44-88 m^3 water. Mature rubber tree in summer need water only 50 L per tree a day while fast-growing tree species like 8 years old eucalypts same size as mature rubber tree, consume 90 L (Kallarackkal and Somen, 1997). Nevertheless, water consumption rate depend on evapotranspiration rate which fluctuate by climate region. In the tropical monsoon climate, rainfall of 125 mm a month, the potential evapotrans piration rate is around 4 mm a day to maintain optimum gaseous exchange (Montieth and Moss, 1977). Physiological status study of plants under water stress is the major indicator of the extent of stress experienced (Mohankrishna *et al*., 1991; Vijayakumar *et al*., 1998).

Table 1: Percent nutrient and component of fertilizer

Formula	Nutrient (%)			Weight of component (%)		
	Nitrogen (N)	Phosphate (P_2O_5)	Potassium (K_2O)	Ammonium sulfate (21% N)	Rock phosphate (25% P_2O_5)	Potassium chloride (60 % K_2O)
1	8	14	3	38	57	5
2	13	9	4	60	34	6
3	8	13	7	36	53	11
4	11	10	7	50	38	12
5	15	0	18	71	0	29
6	12	5	14	57	20	23

Table 2: Dose and time to apply fertilizer before tapping period

Age (month)	Amount (gram/tree)			
	Formula 1 and 3 (loam and sandy)		Formula 2 and 4 (loam and sandy)	
	Granular	Bulk blended	Granular	Bulk blended
2	60	130	-	130
4	60	130	-	130
6	90	200	-	200
11	120	260	-	260
14	120	260	-	260
17	120	260	-	260
23	190	400	-	400
29	190	400	-	400
35	190	400	-	400
41	190	400	-	400
47	-	530	250	530
53	-	530	250	530
65	-	530	250	530
71	-	530	250	530
77	-	530	250	530
83	-	530	250	530

Table 3: Dose and time to apply fertilizer on tapping period

Tapping period (from month 84)	Fertilizer type	Amount (gram/tree)	
		Granular	Bulk blended
1st season of year			
May	Formula 5	0	500
	Formula 6	500	or 600
	Other	500	0
2nd season of year			
September	Formula 5	0	500
	Formula 6	500	or 600
	Other	500	0

Negative hydrological consequences are also of concern for example in the Xishuangbanna prefecture of Yunnan Province, China but current data are too sparse to quantify the extent of the impacts (Guardiola-Claramonte *et al*., 2008).

FERTILIZER

Of all the agro-forestry cropping systems rubber plantations approximate closest to the rainforest system in terms of canopy, leaf litter and in nutrient cycling. Fertilizer inputs are considered very low and soil surrounding rubber trees appears to be enriched by abundant leaf fall nonetheless, sustainability of rubber wood system should include overall lifetime fertilizer consumption to evaluate environmental impact by using Life Cycle Assessment (LCA). Nutrient and composition of fertilizer in each formula is shown in Table 1. Dose and time to apply fertilizer beforeand on tapping period are shown in Table 2 and 3, respectively (TREO, 2010). Rubber tree also need secondary nutrient such as calcium, magnesium. Additional, supplementary element as iron zinc, copper, boron, molybdenum and chloride can be obtained from organic fertilizer. It is recommended that applying fertilizer should bring to halt at 2-3 years before production of latex is uneconomical; the trees are fallen for replanting.

PESTICIDE, HERBICIDE AND INSECTICIDE

The surrounding of rubber plant should be regularly weeded. Weeds on rubber plant are both annual weeds and perennial weeds. Common annual weeds are *Digitaria ciliaris* (Southern crabgrass), *Eleusine indica* (Indian goosegrass), *Echinochloa colana* (jungle rice), *Axonopus compuuressus* (Blanket grass), *Acroceras munroanum* (Ya bai pai), etc. while *Imperata cylindrica* (blady grass), *Pennisetum setosum* (fountain grass), *Cynodon dactylon* (Bermuda grass), *Chromolaena odorata* (Siam weed), *Mikania cordata* (heartleaf hempvine) are perennial. Weeds control can be manually, mechanically and chemically. To prevent weeds in rubber plant can be established environmentally by using cover crops such as *Calopogonium mucunoides*, *Pueraria phaseoloides*, *Centrosema pubescens* and *Calopogonium caeruleum*. On the others hand some species of weeds for need more chemically attention, *Imperata cylindrica* and *Chromolaena odorata* for instance. When necessary, type and amount of herbicide would be applied as shown in Table 4.

Diseases and pests are problems distressed rubberwood and latex quality even to death. The forest trees are major source of infection because they are host to diseases causing pathogens. The rubber plant grown in Thailand is susceptible to certain diseases. Rubber epidemic diseases are mostly caused by fungi.

Table 4: Type and amount of herbicide used

Weeds	Herbicide	Amount per rai*
Imperata cylindrica	Glyphosate (48% SL)	750-1,000 mL/water 100 L
Others	Paraquat (27.6% SL)**	400 mL/water 50 L
	Glyphosate (48% SL)	200 mL/water 50 L

*6.25 rai = 1 h, ** SL = Soluble concentration

Table 5: Insect pest control

Insect pest	Chemical
Coptotermes curvignathus (termite)	Carbosulfan, fipronil
Scarabaeidae (cockchafers)	Carbosulfan, fipronil
Parlatoria proteus curtis (scale insect)	Malathion

Table 6: Disease control

Disease (pathogen)	Chemical
Leaf diseases	
Powdery mildew (*Oidium heveae steinm*)	Benomyl, carbendazim, sulphur
Leaf spot (*Colletotrichum gloeosporioides*)	Zineb, chlorothalonil, benomyl, propineb
Corynespora leaf spot (*Corynespora cassiicola*)	Mancozeb, benomyl
Phytophthora leaf fall (*Phytophthora botryosa*)	Metalaxyl, fosethyl,
Stem and branch disease	
Mouldy rot (*Ceratocystis fimbriata*)	Benomyl, metalaxyl
Pink disease (*Corticium salmonicolor*)	Bordeaux, benomyl, tridemorph
Twig rot of polybagrubber (*Phytophthora nicotianae*)	Dimethomorph, cymoxanil, mancozeb, metalaxyl
Root disease	
White root disease (*Rigidoporus microporus*)	Tridemorph, cyproconazole, hexaconazole, Propiconazole, fenicolonil
Red root disease (*Ganoderma pseudoferreum*)	Tridemorph, difinoconazole
Brown root disease (*Phellinus noxius*)	Tridemorph

Diseases can be classified from different parts of the rubber trees were destroyed including, leaf, stem branch and root diseases. Table 5 and 6 is report of chemical using on rubber plant for pests and diseases controlling, respectively.

STIMULATION

To uphold the highest efficiency of latex production together with maintains table growth and development of rubber in the tapping season, stimulants are commonly used (D'Auzac *et al.*, 1989; Kays and Beaudry, 1987; Nickell, 1989). About 2-Chloroethylphosphonic acid (Ethephon) is one kind belongs to growth regulator group of plant and it is applied to stimulate blooming of some plants. It was discovered in 1961 and is widely used in rubber branch worldwide. Ethephon decomposes toethylene, phosphate and chlorideion in aqueous solutions above pH 4-5. This reaction dominates the fate of the compound in biological systems. It is generally applied 24-48 h before tapping (George and Jacob, 2000).

Even though the exact mechanism of ethylene action is poorly understood on the rubber tree some progresses have been made in physiological and biochemical aspects. Ethylene acted on membrane permeability, leading to prolonged latex flow and on general regenerative metabolism (Coupe and Chrestin, 1989). Ethylene treatment increased the activity of invertase resulting in glycolysis acceleration leading to improving the supply of carbon source for rubber biosynthesis (MesquitaI *et al.*, 2006; Tupy, 1973). Adenylic pool, polysomes and rRNA contents as the indications of metabolic activation were obviously accumulated in laticifers.

Ethephon was found to have low to moderate mobility in soils ranging in texture from loamy sand to peat and silt loam based on soil thin layer chromatography tests. Therefore, the potential for contamination of groundwater appears to be low to moderate (US EPA, 1988). In soil, rapid degradation to phosphoric acid, ethylene and chlorideions was reported (Kidd, 1987; Montgomery, 1993). No information currently available for breakdown of chemical in surface water.

KILLING

There are two methods for felling rubber trees in Thailand. The first one used all around Thailand involves felling the trunk with a chainsaw and then delimbing the trunk. After the felling the land owner can remove the stumps with two methods either through chemical treatment or by using tractors to uproot the stumps. The second option is in use in Southern Thailand together with the first one and consists of felling the entire tree including the root system with a bulldozer and cutting and delimbing the trunk after that. The stumps are either burnt at the plantation site or used later as fuelwood (ITTO, 2000).

In killing old rubber trees during replanting, the industry had long relied on sodium arsenile, acheap and very effective but poisonous arboricide now banned from use. N-butyl ester of 2,4,5-T was introduced in early 1960s to replace sodium arsenite. It is more conveniently used in diesel as a paint on application on intact bark however, it poses serious health hazards. Triclopyr has been found to bean acceptable alternative because it goes well with the common fuel oils such as diesel or kerosene and it is easily applicable on intact bark as a paint on formulation. When formulated in kerosene, the new arboricide is superior to 2,4,5-T in inducing rapid death followed by the decay of the rubber tree or stump (Lim *et al.*, 1983). Figure 3 reviews degradation pathway.

Table 7: Average perimeter, weight and volume of flesh lumber logs of 4 families of rubber tree

Families	Perimeter at height of 1.7 m (cm)	Average wt. of fresh lumber diameter >6 inch (kg)	Average wt. of fresh lumber diameter <6 inch (kg)	Total wt. of fresh lumber log (kg)	Average vol. of fresh lumber diameter >6 inch (m^3)	Average vol. of lumber recovery (m^3)	Average lumber recovery ratio
RRIM 600	81.0	390.0	456.4	846.4	0.361	0.094	26.0
BPM 24	78.8	342.6	452.6	815.2	0.356	0.073	20.7
RRIT 251	79.6	309.8	522.0	831.8	0.299	0.097	29.7
PB 235	81.0	707.4	239.8	947.2	0.665	0.182	25.6

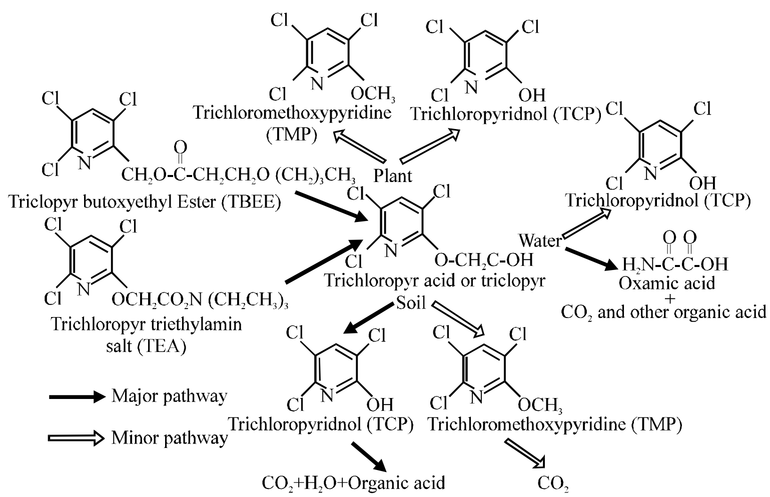

Fig. 3: Triclopyr degradation

YIELD OF LOG WOOOD

Lumber recovery is another dilemma held back development of Parawood industrial sincelow yield of production. The normal sawing line always consist of transport of logs, primary sawingwith headrig bandsaw with carriage, secondary breakdown of cant with small bandsaw andprocessing of flitch with small bandsaw. The technique flow is shown in Fig. 4.

From previous study, Parawood lumber recovery is 25% average. The remaining are wood slab 50% and sawdust 25%. Table 7 shows average perimeter, weight and volume of fleshlumber logs of 4 families of rubber tree; RRIM 600, BPM 24, RRIT 251 and PB 235 at diameter lessand >6 inch. Comparing of lumber recovery volume of fresh log and sawed wood, among four families, PB235 provide the highest yield since, PB 235 has topmost shape and less branch. On the other hand, RRIT 251 returns the least recovery ratio because of its bush shape and lot of branch. In case ofBPM 24, it has a lot of defects from its knot there fore its average lumber recovery ratio is low. There is no sawn wood grading for Parawood but it is sawn in the falling grade. However, some sawmills claim to have a class system selling two or three different classes (A, A/B and C). The sawing technique also is important to processing efficiency, lumber quality and value added to products. Figure 5 indicates the utilization of one rai Parawood.

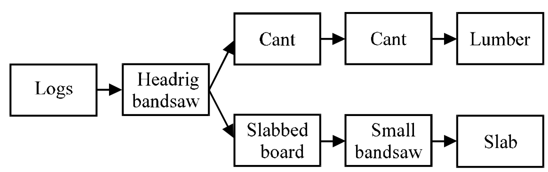

Fig. 4: Technique flow of sawmill

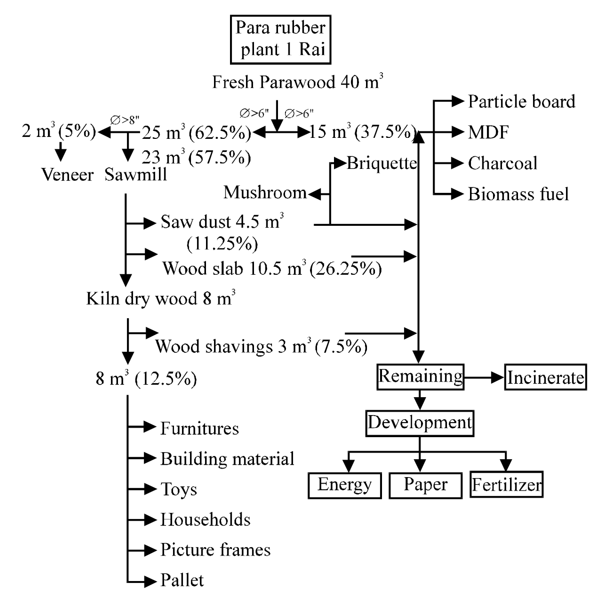

Fig. 5: Utilization of one rai Parawood

WOOD PRESERVATION

The timber should be treated by pressure or diffusion process promptly after it is cut for preventing stain fungi and insects. Rubber wood protection is classified by temporary protection and long-term protection. For temporary some insecticides are included: deltamethrin cypermethrin, permethrin, cyfluthrin, bifenthrin, chlorpyrifos, imidacloprid, fipronil, chlorfenapyr, etc.

Some fungicides are included: chlorothalonil, copper oxine, MBT, TCMTB, carbendazim, benomyl, IPBC, isothiazolinone, fenpropimorph, quatery ammonium chloride, propiconazole, etc. Sodium pentachlorophenol is not recommended for its high toxic. And its use has been strictly restricted or prohibited in some countries such as Japan and some European counties.

When the Parawood is dried, no stain and mold fungi as well as decay fungi occur but powerbeetles can attack it, so diffusion process or pressure treatment allow the preservative to be fully penetrated into sapwood and give long term protection. Boron is the common preservative for the treatment for its high diffusion ability. The treated products can only be used indoor circumstance for itis leachable in rain.

The schedule of vacuum pressure of treatment begins with initial vacuum let the air inside thecell out for the preservative penetrate easily then fill the preservative under vacuum condition. Release the vacuum after filling the preservative, pressure for a period of time until the retention reach the target. After that release the pressure, pump out the preservative from the vessel. Finally, keep vacuum for a period to recover the excess preservative. Condition and duration of each stage are shown in Table 8. According to use category and specification for preservative treated wood, retention of B_2O_3 2.8 kg/m^3 is equivalent of the retention 6.0 kg/m^3 of boric acid/borax (10 H_2O) at ratio 1:1. This based on B content 11.3% in $Na_2B_4O_7$-10H_2O, B content 17.5% in H_3BO_3 and B content 31% in B_2O_3. For example if the treated wood is used for interior dry condition when preservative absorption is 220 kg/m^3, concentration of boric acid/borax should be 2.7% weight of boric acid/borax for preparing 1000 kg should be 13.5 kg each.

Some cuts of Parawood and may be lighter or darker than others. To obtain a uniform colorfor use in furniture, the choice is generally limited to a color equal to or darker than the natural color of the wood. The only way to avoid this darkening is to bleach the wood or use a bleaching toner onthe wood together with preservation agents (Currier, 1983). There are two reasons for the discoloration of wood. The first is damage, drying of branches, disease, etc. in live trees (Shigo and Hillis, 1973). The second is oxidation, iron stains, fungi discoloration and chemical stains occurring on wood cut from trees. This kind of discoloration degrades the quality of wood material. Moreover, acidic chemicals bleach decreases wood strength. The bleaching chemicals normally used were: sodium hydroxide (NaOH), Hydrogen peroxide (H_2O_2), Calcium Hydroxide ($Ca(OH)_2$), Hypochlorite acid (HClO) and Hydrochloric acid (HCl). Additionally, acetic acid (CH_3COOH) was used for neutralization.

Table 8: Condition and duration of each

Phases	Pressure (MPa)	Duration (min)
Initial vacuum	0.083-0.099	30-45
Pressure	1.2-1.4	60-120
Final vacuum	0.053-0.086	10-20

As described, energy and hazardous chemical consumption are environmental drawback point of this procedure. Furthermore, during the vacuum pressure treatment, the Moisture Content (MC) of timber may be 50-100% that leads to the necessary of next procedure, kiln drying.

KLIN DRYING OF PARAWOOD

The keys to prevent Parawood from stain fungus or decay rely on not only chemical treatment but also immediate drying so that the moisture content reaches a low level to destroy the live conditions of fungus. Kiln drying is the step requiring massive energy. Many researchers report that 40-80% of energy used in Parawood processing is from kiln drying procedure to remove moisture content of timber. Moreover, some energy may loss by conduction through walls and ceiling, convection with moist air released to the atmosphere and also radiation. Energy consumption of kiln drying depends on physical properties of Parawood, drying process and efficiency of drying chamber. Heat consumption for kiln drying is 1.5-3.0 times of energy used for water evaporation (2.3 MJ per kg water). Smaller chamber normally consumes more energy per one kilogram water than the bigger. Among soft wood and hardwood, approximately 4.7-7.0 MJ kg^{-1} is needed for drying.

FINGER JOINT AND LAMINATING

After Parawood processed through preservation and kiln drying, it is capable produced to various products. But it is still limited because of its narrow and short shape it cannot be used for work requiring the wood width. Therefore, it need to be processed to finger joint and laminated at desired size. Process starts with cutting the length down to about 25-36 cm to minimize warping orbending. Then, slide to open the surface to desired thickness and slide its side to desired width. Graded and sorted Parawood having the same shade of color then are connected by finger joint technique. Finger-joints have been developed because it is not possible to make strong butt joints bygluing the end grain of adjacent boards. In finger-joints the glued surfaces are on the side grain rather than end grain and the glue line is stressed in shear rather than in tension.

Normally in wood processing, adhesives used as glue are two composites mixture (adhesive and hardener) such as polyvinyl alcohol with isocyanate, polyvinyl acetate with chromium or aluminium salt. Other adhesive used for wood laminating are for example, elastomer, urea formaldehyde, urea melamine formaldehyde. Moreover, each glued area requires pressure approximately at 5-8 kg/cm^2 (0.5-0.6 MPa) and some heat to rise temperature up to 60-70°C. As given information above this process may cause toxic to both researchers and user. Furthermore, energy consumption also is required for this process.

CONCLUSION

Researchers describe above in order to answer the question that Parawood is environmentally friendly material or not researchers need to know about the process of acquisition. Although, some may judge that Parawood is a waste product from the rubber but according to the principles of life cycle assessment if any product has price value, allocation for the environment load is necessary. Parawood must be responsible for the environment load from the process of planting and maintenance which involves plenty of chemicals and might cause toxicity to human. Moreover, log and lumber processing consume additional chemicals and energy. Therefore, earlier to make a decision, life cycle inventory, LCI is necessary established carefully.

REFERENCES

Aweto, A.O., 1995. Organic carbon diminution and estimates of carbon dioxide release from plantation soil. Environmentalist, 15: 10-15.

Balsiger, J., J. Bahdon and A. Whiteman, 2000. Asia-Pacific Forestry Sector Outlook Study: The Utilization, Processing and Demand for Rubberwood as a Source of Wood Supply. FAO, Bangkok.

Chaudhuri, D., K.K. Vinod, S.N. Potty, M.R. Sethuraj, J. Pothen and Y.A.N. Reddy, 1995. Estimation of biomass in Hevea clones by regression method: Relation between girth and biomass. J. Rubber Res. Inst., 8: 113-116.

Coupe, M. and H. Chrestin, 1989. Physico-Chemical and Biochemical Mechanisms of Hormonal (Ethylene) Stimulation. In: Physiology of Rubber Tree Latex, J. d'Auzac, J.L. Jacob and H. Chrestin (Eds.). CRC Press, Boca Raton, FL, USA., pp: 295-319.

Currier, G.M., 1983. Furniture Finishing Processes and Systems. Reliance Universal Inc., High Point, NC, USA., pp: 40-44.

D'Auzac, J., J.L. Jacob and H. Chrestin, 1989. Physiology of Rubber Tree Latex. CRC Press, Boca Raton, FL., USA.

Dey, S.K., D. Chaudhuri, K.K. Vinod, J. Pothen and M.R. Sethuraj, 1996. Estimation of biomass in Hevea clones by regression method: 2 relation of girth and biomass for mature trees of clone RRIM 600. Indian J. Nat. Rubber Res., 9: 40-43.

George, P.J. and C.K. Jacob, 2000. Natural Rubber: Agromanagement and Crop Processing. Rubber Research Institute, India, pp: 239-248.

Guardiola-Claramonte, M., P.A. Troch, A.D. Ziegler, T.W. Giambelluca, J.B. Vogler and M.A. Nullet, 2008. Local hydrologic effects of introducing non-native vegetation in a tropical catchment. Ecohydrology, 1: 13-22.

ITTO, 2000. Status of Rubberwood utilization and marketing in Thailand. International Tropical Timber Organization, Technical Report, pp: 89.

ITTO, 2006. Achieving the ITTO objective 2000 in Thailand: Report of the diagnostic mission. Report Submitted to the International Tropical Timber Council by the Diagnostic Mission Established Pursuant to Decision 2, International Tropical Timber Organization.

Kallarackkal, J. and C.K. Somen, 1997. An ecophysiological evaluation of the suitability of *Eucaliptus grandis* for planting in the tropic. For. Ecol. Manage., 95: 53-61.

Karthikakuttyamma, M., P.R. Suresh, P. Prasannakumari, V. George and R.S. Aiyer, 1998. Effect of continuous cultivation of rubber (*Hevea brasiliensis*) on morphological features and organic carbon, total nitrogen, phosphorous and potassium contents of soil. Indian J. Nat. Rubber Res., 11: 73-79.

Kays, S.J. and R.M. Beaudry, 1987. Techniques for inducing ethylene effects. Acta Hort., 201: 77-116.

Kidd, H., 1987. The Agrochemicals Handbook. The Royal Society of Chemistry, Nottingham, England.

Krishnakumar, A.K., T. Eappen, N. Rao, S.N. Potty and M.R. Sethuray, 1990. Ecological impact of rubber (*Hevea brasiliensis*) plantations in north east India. 1. Influence on soil physical properties with special reference to moisture retention. Indian J. Nat. Rubber Res., 3: 53-63.

Li, H., T.M. Aide, Y. Ma, W. Liu and M. Cao, 2007. Demand for rubber is causing the loss of high diversity rain forest in SW China. Biodivers. Conserv., 16: 1731-1745.

Li, H., Y. Ma, T.M. Aide and W. Liu, 2008. Past, present and future land-use in Xishuangbanna, China and the implications for carbon dynamics. For. Ecol. Manage., 225: 16-24.

Lim, C.K., J.M. Rideout and D.J. Wright, 1983. High-performance liquid chromatography of naturally occurring 8-, 7-, 6-, 5- and 4-carboxylic porphyrin isomers. J. Chromatogr., 282: 629-641.

Mandal, D., R.P. Singh, D. Chaudhuri, A.C. Sarma and H.K. Deka, 2001. Influence of rubber cultivation on physico-chemical properties of soil: A case study. Indian J. Nat. Rubber Res., 14: 71-74.

MesquitaI, A.C. L.E.M. de OliveiraI, P. Mazzafera and N. Delu-Filho, 2006. Anatomical characteristics and enzymes of the sucrose metabolism and their relationship with latex yield in the rubber tree (*Hevea brasiliensis* Muell. Arg.). Braz. J. Plant Physiol., 18: 263-268.

Mohankrishna, T., C.V.S. Bhaskar, P.S. Rao, T.R. Chandrasekhar, M.R. Sethuraj and K.R. Vijayakumar, 1991. Effect of irrigation on physiological performance of immature plants of Heiea brasiliensis in North Konkan. Indian J. Nat. Rubber Res., 4: 36-45.

Montgomery, J.H., 1993. Agrochemicals Desk Reference: Environmental Data. Lewis Publishers, Chelsea, MI., USA.

Montieth, J.L. and C.J. Moss, 1977. Climate and the efficiency of crop production in Britain and Discussion. Philos. Trans. R. Soc. London B Biol. Sci., 281: 277-294.

Nickell, L.G., 1989. Plant Growth Regulating Chemicals. CRC Press, Boca Raton, FL., USA.

Niskanen, A. and O. Saastomoinen, 1996. Tree plantation in the Philippine and Thailand: Economics, social and environmental evaluation. UNU World Institute for Development Economics Research.

Philip, A., V. Philip, E.S. George, K.I. Punnoose and M. Mathew, 2003. Leaf litter decomposition and nutrient release in a fifteen year old rubber plantation. Indian J. Nat. Rubber Res., 16: 81-84.

Qiu, J., 2009. Where the rubber meets the garden. Nature, 457: 246-247.

Ren, M., M. Cao, J.W. Tang, Y. Tang and J.H. Zhang, 1999. A comparative study on litterfall dynamics in a seasonal rain forest and a rubber plantation in Xishuangbanna, SW China. Acta Phytoecol. Sin., 23: 418-425.

Rodrigo, V.H.L., E.S. Munasinghe and U.A.D.P. Gunawardena, 2005. Development of a simple protocol for *In situ* assessments of timber, biomass and carbon in the rubber layer. Proceedings of the International Natural Rubber Conference, November 6-8, 2005, Rubber Research Institute of India, Cochin, India, pp: 246-255.

Rojo-Martinez, G.E., J. Jasso-Mata, J. Vargas-Hernandez, D. Palma-Lopez and A. Velazquez-Martinez, 2005. Aerial biomass in commercial rubber plantations (*Hevea brasiliensis* Mull. Arg.) in the state of Oaxaca, Mexico. Agrociencia, 39: 449-456.

Schroth, G., S.A. D'Angelo, W.G. Teixeira, D. Haag and R. Lieberei, 2002. Conversion of secondary forest into agroforestry and monoculture plantations in Amazonia: Consequences for biomass, litter and soil carbon stocks after 7 years. For. Ecol. Manage., 163: 131-150.

Sethuraj, M.R. and J. Jakob, 1977. Rubber and the environment. Second Meeting of the Expert Group, Project Promotion of Natural Rubber as Environmental Friendly Raw material and Renewable Resource, Cochin, India.

Sethuraj, M.R., S.N. Potty, K.R. Vijayakumar, A.K. Krishnakumar and P.S. Rao *et al*., 1989. Growth performance of Hevea in the non-traditional regions of India. Proceedings of the RIM Rubber Growers' Conference, (RIMRGC'89), India, pp: 212-227.

Shigo, A.L. and W.E. Hillis, 1973. Heartwood, discolored wood and microorganisms in living trees. Ann. Rev. Phytopathol., 11: 197-222.

Shorrocks, V.M., J.K. Templeton and G.C. Iyer, 1965. Mineral nutrition, growth and nutrition cycle of *Hevea brasiliensis*. III. The relationship between girth and shoot dry weight. J. Rubber Res. Inst., 19: 85-92.

TREO, 2010. Annual report. Bangkok, Thailand.

Tomich, T., P. van Noordwijk, S. Budidarsono, A. Gillison and T. Kusumanto *et al*., 2000. Agricultural Intensification, Deforestation and the Environment: Assessing Tradeoff in Sumatra, Indonesia. In: Tradeoffs or Synergies?: Agricultural Intensification, Economic Development and the Environment, Lee, D.R. and C.B. Barrett (Eds.). CAB, New York, USA.

Tupy, J., 1973. The regulation of invertase activity in the latex of *Hevea brasiliensis* Muell. Arg The effects of growth regulators, bark wounding and latex tapping. J. Exp. Bot., 24: 516-524.

US EPA, 1988. Guidance for the Reregistration of Pesticide Products Containing Ethephon as the Active Ingredient. U.S. Environmental Protection Agency, Washington, DC, USA., Pages: 118.

Van Noordwijk, M., T. Tomich, R. Winahayu, D. Murdiyarso, S. Suyanto, Partoharjono and A.M. Fagi, 1995. Alternatives to Slash-and-Burn in Indonesia. Summary Report of Phase 1, ASB Indonesia Report Number 4.

Vijayakumar, K.R., S.K. Dey, T.R. Chandrasekhar, A.S. Devakumar, T. Mohankrishna, P. Sanjeeva Rao and M.R. Sethuraj, 1998. Irrigation requirement of rubber trees (HeIea brasiliensis) in the subhumid tropics. Agric. Water Manage., 35: 245-259.

Wauters, J.B., S. Coudert, E. Grallien, M. Jonard and Q. Ponette, 2008. Carbon stock in rubber tree plantations in Western Ghana and Mato Grosso (Brazil). For. Ecol. Manage., 255: 2347-2361.

Yang, J.C., J.H. Huang, J.W. Tang, Q.M. Pan and X.G. Han, 2005. Carbon sequestration in rubber tree plantations established on former arable lands in Xishuangbanna, SW China. Acta Phytoecol. Sinica, 29: 296-303.

Yang, J.C., J.H. Huang, Q.M. Pan, J.W. Tang and X.G. Han, 2004. Long-term impacts of land-use change on dynamics of tropical soil carbon and nitrogen pools. J. Environ. Sci., 16: 256-261.

Zhang, H. and G.L. Zhang, 2003. Microbial biomass carbon and total organic carbon of soils as affected by rubber cultivation. Pedosphere, 13: 353-357.

Zhang, H. and G.L. Zhang, 2005. Landscape-scale soil quality change under different farming systems of a tropical farm in Hainan, China. Soil Use Manage., 21: 58-64.