LAND ALLOCATION AND TRANSPORTATION NETWORK PLANNING FOR CRUDE PALM OIL PRODUCTION IN THAILAND

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Abstract

This research investigates the issue of determining the sizes of oil palm plantation in four different regions (north, northeast, central, and south) of Thailand and the transportation network between the regions from plantation to mill. A methodology is developed based on optimization model that will allow policy makers to decide how much land should be allocated for plantation in each region and to specify transportation route moving fresh fruit brunches (FFB) to crushing mills to satisfy demand and minimize cost of management in crude palm oil production when given different regional conditions of the size of harvesting area, yield, percentage of extracted oil, crushing mill capacity, and cost. The regional constraints are considered in the model when FFB are allowed to transport to mills in other regions. A numerical experiment is conducted to illustrate the model.

Keywords: Crude palm oil management, Land allocation, Production and distribution, Optimization

1. INTRODUCTION

Palm oil is widely used in many industries. It can be found in many products ranging from food purposes (industrial frying, chocolate, margarine, cereals, crisps, sweets and baked goods, etc.) to non-food purposes (such as soaps, washing powders, cosmetics, plastics, steel, textile, animal feedstuffs, and bio fuel) (Foo and Hameed, 2009; Sheil et al., 2009, Koh and Wilcove, 2008). It is being used increasingly for non-food applications e.g. biofuel and biomass therefore the demand is growing. In 2012, United States Department of Agriculture put Thailand among the top five annual growth rate productions of palm oil in the world. FAO also reveals that Indonesia, Malaysia and Thailand are ranked the top three palm oil producing countries. The increased demand of palm oil has drawn many attentions towards a large-scale plantation development (Sundaram et al., 2004). The growth of the palm oil industry has negative impacts on environment and also increases the cost of living near the processing plant in Malaysia (Kathurai and Khan, 2002). It also negatively affects the social aspect

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causing native people to lose their land and conflicts over land use and not achieving sustainable livelihood improvement for smallholder farmers (McCarthy et al., 2012; Laurance et al., 2010; McCarthy and Zen, 2010; Rist et al., 2010; CAO 2009; Colchester et al., 2006;). Unlike Malaysia and Indonesia, large estates are rare in Thailand (Dallinger, 2011; Vermeulen and Goad, 2006). The majority is independent smallholders; roughly 80% of the palm oil produced in Thailand comes from smallholders (Seegräf et al., 2010). Preechajarn (2010) explains that these farmers act independently from crushing mills – no contracts or formal arrangement in planting and selling fresh fruit brunches (FFB). With the practice of several smallholder plantations, it serves livelihood improvement for the farmers; however, it becomes challenges for palm oil industry development. By regulation and a limitation of non-forest area, Thailand has limited area to expand the plantation (Chavananand, 2011). Palm Oil Crushing Mill Association also reports that palm oil mills, overall, are overcapacity (Chavananand, 2011). These challenges lead to high operating cost and strong competition between mills; hence, it is difficult to compete in the world market. On the other hand, the domestic demand is also increasing. In 2010, Thailand produces 1,288,000 tons of crude palm oil (CPO) of which serves in several industries: cooking oil 30%, margarine shortening 5%, biodesel 35%, food industry 17%, soap industry 2%, animal feeds 2%, and exported 9%. The plantation is approximately 90% concentrated in the southern provinces of Thailand – Krabi, Surat Thani and Chumphorn accounted for 72.1% of the total planted area in 2008 (Univanich Palm Oil PCL, 2011). The plantation also has been expanded in northeastern provinces. Even though smallholder farming can play a fundamental role in the strategic goals for social inclusion and income distribution to rural areas a question remain, how much land should be allocated to plantation in each region and to specify transportation route moving FFB to crushing mills to satisfy the crude palm oil demand and minimize cost of management from plantations to mills, as a part of demand-supply equation that required by Thai Palm Oil Industry board member (Chavananand , 2011). Most research focuses on solving large-scale plantation and waste utilization (Chiew et al, 2011; Haslenda and Jamaludin, 2011; etc). Few articles like Leao et al. (2011) work on small farmers but it covers Brazilian supply chain. Chavananand (2011) investigates the background of Thai palm oil supply chain and talks about future overview and challenges.

2. CRUDE PALM OIL PRODUCTION

Oil palm has 20-30 years of an economic life; and fresh fruit brunches can be harvested after three years of planting, with its maximum yield in the 12th or 13th year (Foo and Hameed, 2009). The fruit consists of peel, shell, kernel, and mesocarp (pulp) as shown in Figure 1. When pressed, the fruitlets' mesocarp gives crude palm oil (CPO) and the kernel gives crude palm kernel oil (PKO or CPK). In leading palm oil producing country like Malaysia, CPO has an oil extracted rate (OER) about 20%. The average OER in Thailand is

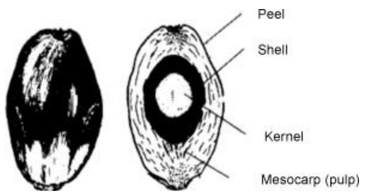

Figure 1: Fresh oil palm fruit image with its longitudinal section (Guo and Lua, 2001).

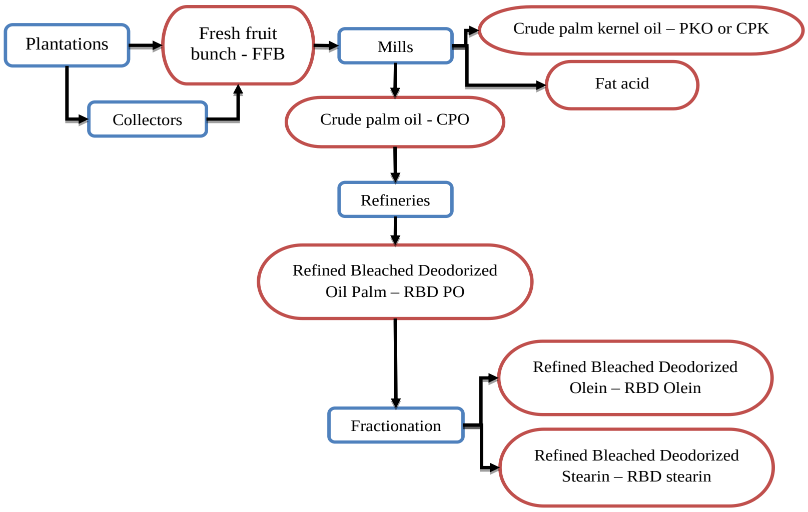

Figure 2: Palm oil production process from upstream to downstream supply chain. (Suksa-ard and Raweewan, in press)

lower than 20% due to lower quality handling from seed selection to crushing mill in the chain. Based on a composition chart of the palm fruit production processes presented in Muttamara et al. (1987), we illustrate the supply chain in Figure 2. Our work focuses on production and distribution in the chain from plantation to the production of CPO and CPK.

3. FROM PLANTATION TO CRUSHING MILL, SUPPLY CHAIN MANAGEMENT IN THAILAND

Supply chain activities in crude palm oil production consist of palm trees planting and cultivation, FFB harvesting and transportation, and FFB crushing at crushing mills. According to these activities, the major stakeholders are plant nurseries growing young palm trees from the fruits, farmers planting and taking care of the trees, collectors hired to harvest and transport mature FFB, and crushing mills producing crude palm oil.

Farmers buy young trees from nurseries that are certified by government agency or from national palm research centers. Young trees are then cultivated in plantation. Once FFBs are mature, there are several management styles to sell FFB to crushing mills. We conclude these styles from field data collection in the south of Thailand.

1) Farmers hire collectors to harvest and transport them. Collectors are paid by weight of FFB. These FFBs are either sold directly to crushing mills or to ramps that gather FFBs for economy of scale before selling them to crushing mills.

2) Sometimes farmers have agreement with ramps or crushing mills to harvest and transport FFBs. Some ramps act as crushing mills' collectors. Ramps ask 300-500 baht per tree for the cost of harvesting from farmers.
3) In some regions, farmers co-op acting as ramp play crucial role to collect FFB from members and sell them to crushing mills. The practice can control quality of purchasing FFB and offer good price to farmers.

Purchasing price per one kilogram of FFB is determined daily by crushing mills. The price of loose fruits is higher than fruit brunches. FFBs at ramps are then either transport to small crushing mills or to bigger ramps before transporting to big crushing mills. The process from plantations to crushing mills is illustrated in Figure 3. For good quality of FFBs, after they are harvested, they should be transported within 24 hours to crushing mills to produce CPO. However, sometimes it takes two days. This delay causes FFB weight to drop approximately 20% and increases acid in FFB contributing to lower CPO quality.

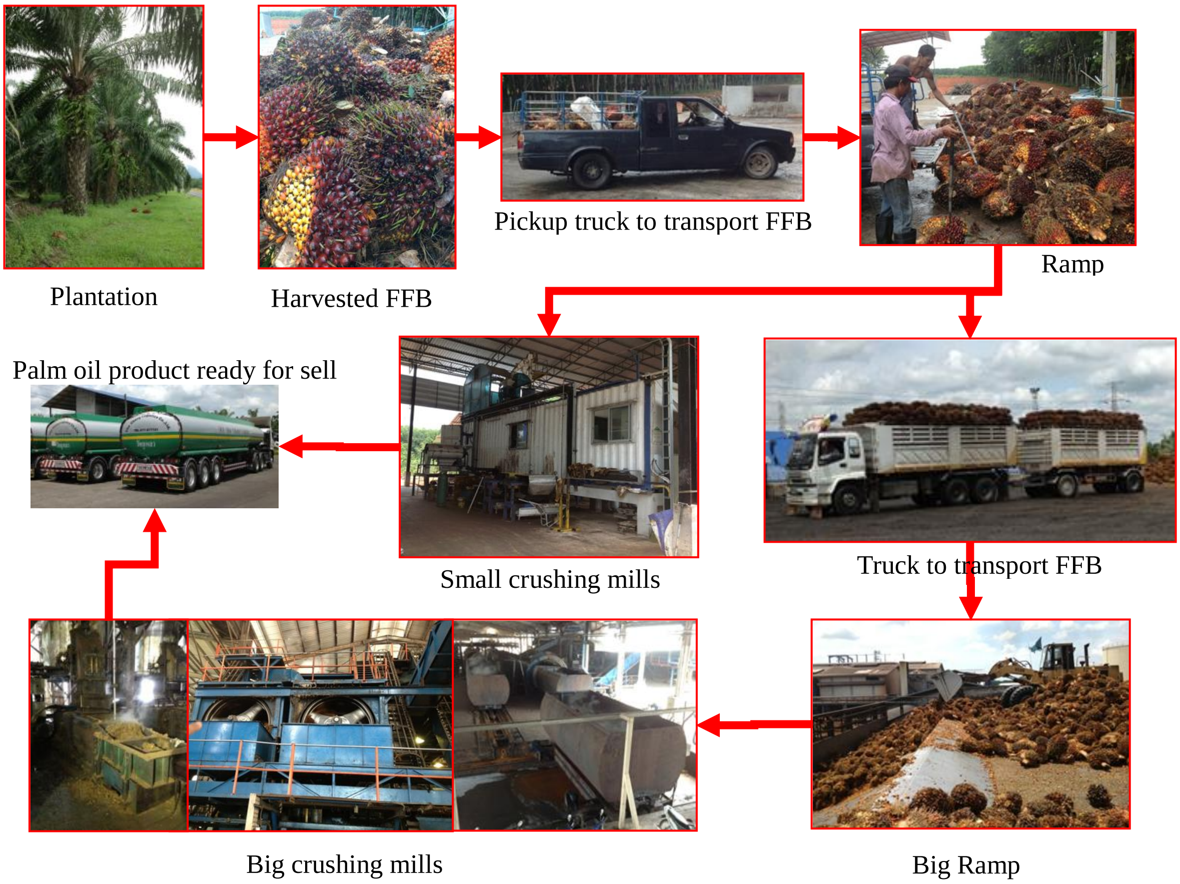

Figure 3: Palm oil production process from plantation to crushing mills.

4. MATHEMATICAL MODEL

We assume FFBs are transported to crushing mills within 24 hours after harvesting.

Given minimum demands of crude palm oil products and different condition in each region (the size of harvesting area, yield, percentage of extracted oil, crushing mill capacity, and cost), a mathematical model is proposed to assist policy makers to decide how much land should be allocated for plantation in each region and to specify distribution route moving FFB to crushing mills to minimize cost of management in CPO and CPK production.

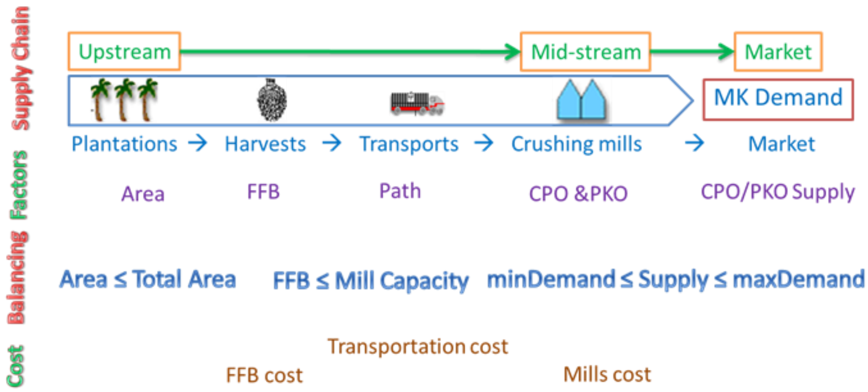

Figure 4: Model overview.

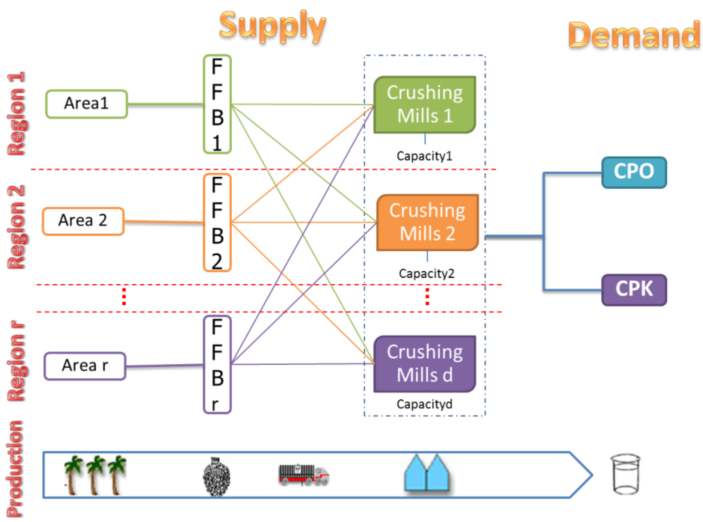

Figure 5: Distribution network from plantations to mills to produce CPO and CPK.

4.1 Conceptual Model

A conceptual model is displayed in Figures 4 and 5. Figure 4 is an overview of the model. The top layer shows the supply chain; the next layer below emphasizes key factors (plantations area and harvesting FFB done by smallholder farmers, distribution network on truck route in the same region and across regions, focusing on CPO and CPK production). The third layer lists constraints to balance demand and supply. The final layer shows related costs that will be explained in detail in the next section. There are plantations and crushing mills that are already exist in four regions (north, northeast, central, and south) of Thailand; Figure 5 shows a distribution network set up in the proposed model.

4.2 Mathematical Programming Model

This section presents parameters, decision variables, and a proposed model.

Set and indices:

I = *set of palm oil product; {CPO, CPK}*

Parameters:

R = *total number of region*

Q_r = *total available mature area (rais) in region r*

y_r = *yield (tons) per area unit in region r*

M_d = *mill's capacity (tons) per year at mill in region d*

min_i = *minimum demand (tons) of commodity product j*

$e_{i,d}$ = *oil extraction rate (%) of palm oil product i at mill in region d*

b_r = *FFB purchasing cost (baht) per unit in region r*

f_{rd} = *transportations cost (baht) per FFB unit (tons) from plantation in region r to mill in region d*

c_d = *mill cost (baht) per unit of FFB (tons) for produce CPO & CPK from FFB in region d*

$o_{i,d}$ = *supply of palm oil product i (tons) in region d*

Decision variables:

q_r = *required land size (rais) for plantation in region r*

p_{rd} = *amount of FFB (tons) transported from plantation region r to mill in region d*

Mathematical programming model

Objective function;

$$minimize \sum_{\forall r \in R} q_r y_r b_r + \sum_{\forall r \in R} \sum_{\forall d \in R} p_{rd} f_{rd} + \sum_{\forall d \in R} \sum_{\forall r \in R} c_d p_{rd} \tag{1}$$

Subject to;

$$q_r \leq Q_r \tag{2}$$

$$q_r y_r \geq \sum_{d=1}^{R} p_{rd}, \qquad r = 1, \dots, R \tag{3}$$

$$M_d \geq \sum_{r=1}^{R} p_{rd}, \qquad d = 1, \dots, R \tag{4}$$

$$o_{i,d} = e_{i,d} \sum_{r=1}^{R} p_{rd}, \qquad d = 1, \dots, R;\ i \in I \tag{5}$$

$$\sum_{d=1}^{R} o_{i,d} \geq min_i, \qquad i \in I \tag{6}$$

$$q_r \geq 0,\ p_{rd} \geq 0 \tag{7}$$

Equation (1) represents the objective function, which aim to minimize total cost of palm oil productions to satisfy palm oil products' demand. The total cost is the summation of total FFB purchasing cost, total transportation costs of FFB, and total production cost of palm oil product (CPO, CPK) at crushing mill. Constraint (2) limits the required land size for plantation not to exceed the total available area in each region. Constraint (3) states that the amount of FFB transported from region r to crushing mills in region d will be less than or equal to amount of FFB produced in plantation in region r, defined by the term $q_r y_r$. Constraint (4) states that the amount of FFB transported from plantation in region r to crushing mills in region d would not be more than the mill's capacity. Constraint (5) states that palm oil product i at crushing mills in region d is extracted from FFB that transported from all plantation in region r. Constraint (6) states that the total supply of palm oil product i should satisfy the minimum demand of palm oil products. Constraint (7) is non-negativity condition.

5. NUMERICAL EXAMPLE

5.1 Numerical Input

Based on Chavananand (2011), the plantation zone is located in northern, northeastern, central, and southern zones of Thailand; crushing mills only exist in three zones (northeastern, central, and southern zone). The values of parameters in this study are collected from Thai palm oil industry. Information in Table 1 is collected from directed interview and various secondary data sources in Thailand. Market demand of CPO and CPK are obtain from Office of Agricultural Economics (2012b) of Thailand that reports the demand in 2012. The domestic use is 1.559 million tons (consume 0.933 and biodiesel 0.626) and export is 411,926 tons. Therefore, we set minimum demand of CPO to 1.97 million tons. We also assign 0.197 million tons to minimum demand of CPK, or 10 % of minimum demand of CPO.

Table 1: Numerical input.

Factors	**Unit**	**North (1)**	**Northeast (2)**	**Central (3)**	**South (4)**
Mature area[1]	rai	18,326	75,598	735,127	3,446,530
Yield[1]	ton/rai	0.576	1.334	1.557	2.922
FFB cost[2]	Baht/ton	4,100	4,100	4,100	4,100
Mills' cost[3]	Baht/ton	N/A	500	500	500
Mills' Cap.[4]	ton/year	N/A	144,000	1,418,400	18,676,800
OER for CPO[5]	% of FFB	N/A	17%	17%	17%
OER for CPK[5]	% of FFB	N/A	5%	5%	5%

N/A = no mills or refineries in the region, 6.25 rai = 1 ha.

[1] Office of Agricultural Economics, 2012a.

[2] Office of Agricultural Economics, 2012b.

[3] Direct interview of crushing mill managers.

[4] Chavananand , 2011

[5] Research institute, Suratthani Rajabhat University, 2012

Table 2: Transportation cost.

Unit in baht	**North**	**Northeast**	**Central**	**South**
North	N/A	372	384	652
Northeast	N/A	182	391	712
Central	N/A	391	174	425
South	N/A	712	425	175

N/A = no mills in the region

Transportation cost estimated on average cost for 21-ton trucks from plantations r to mills d in unit of baht per ton, used cost rate from DX Innovation Co., Ltd as show in Table 2.

5.2 Result

The optimization models were written in IBM ILOG CPLEX. Numerical result is illustrated in Figure 6. The minimum cost of supply chain is 55,335.464 million baht. All lands that are available in all regions should be completely used; but it is not enough to satisfy the minimum demand of CPO. To satisfy it, a model suggests that the land in the southern region should be added 89,486.101 rais; extended from 3,446,530 to 3,536,016.101 rais. As a result, the desired minimum demand of CPO is met and the CPK demand is satisfied at 579.412 kilotons, passing the CPK minimum demand. Policy makers can interpret this result that plantation in four regions and its corresponding yield are not enough to satisfy the CPO demand in the market. For the distribution, FFBs are transported to crushing mills in the same region except FFBs in the north are transported to crushing mills in the northeastern region.

Let’s look at crushing mill capacity. The total capacity of crushing mills in northeastern region is 144 kilotons per year; however, it is utilized only 111.404 (100.848+10.556) kilotons per year or 77% of utilization. Likewise, it is 81% and 55% of utilization in the central region and southern region, respectively. It is clear that total capacity of crushing mills in the south is not well balance with FFB production in the region. This agrees with Chavananand (2011)’s statement that crushing mills in the country is overcapacity. Using this purposed model, we gain the insight that, the balance between mills capacity and FFB production has serious problem in the southern region.

6. CONCLUSION AND FUTURE RESEARCH

A methodology has been proposed that policy makers need quantitative tools to assist in making decision regarding allocation of plantation area and determining pattern of distribution network to satisfy national demand and minimize cost of operation from plantation to crushing mill. This research explores such tools that determined how much land should be planted and harvested oil palm in what region (northern, northeastern, central, and southern). Example was presented to illustrate the model.

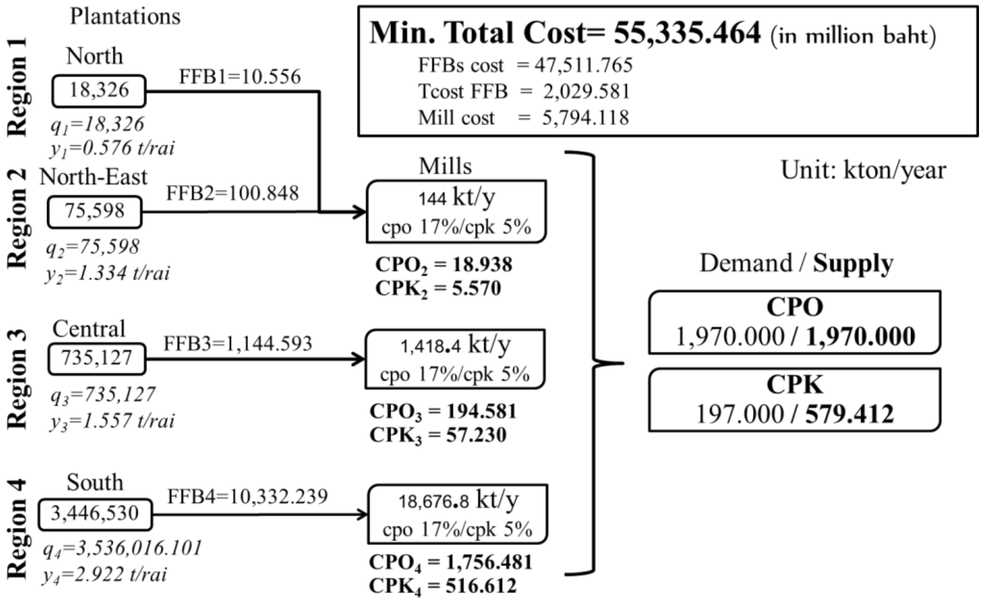

Figure 6: Numerical output.

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REFERENCES

CAO (2009) *CAO Audit of IFC's investments in: Wilmar Trading (IFC No. 20348) Delta–Wilmar CIS (IFC No. 24644) Wilmar WCap (IFC No. 25532) Delta–Wilmar CIS Expansion (IFC No. 26271),* Office of the Compliance Advisor/Ombudsman (CAO) for the International Finance Corporation (IFC), Washington, DC.

Chavananand, K. (2011) Future of the Thai Palm Oil Industry. *Paper Presented at: Palmex Thailand 2011 Conference, IMPACT, Bangkok.*

Chiew, Y. L., Iwata, T. and Shimada, S. (2011) System analysis for effective use of palm oil waste as energy resources. *Biomass and Bioenergy,* 35**,** 2925-2935.

Colchester, M., Watch, S. and Programme, F. P. (2006) *Promised land: palm oil and land acquisition in Indonesia : implications for local communities and indigenous peoples*. Perkumpulan Sawit Watch.

Dallinger, J., (2011) *Oil palm development in Thailand: economic, social and environmental considerations.* In M. Colchester and Sophie Chao *(ed),* with Jonas Dallinger, H. E. P. S.

V. T. D. J. V.. *Oil Palm Expansion in South East Asia: Trends and implications for local communities and indigenous peoples* (Perkumpulan Sawit Watch), chapter1.

de Lima Montenegro Duarte, A.R.C., Bezerra, UH., de Lima Tostes, ME., and da Rocha Filho, G.N. (2008) Evaluating the energy potential of palm oil for the generation of electricity in isolated communities, *Power and Energy Magazine, IEEE*, 23, 51–57.

Foo, K. Y. and Hameed, B. H. (2009) Utilization of biodiesel waste as a renewable resource for activated carbon: Application to environmental problems. *Renewable and Sustainable Energy Reviews,* 13**,** 2495-2504.

Guo, J. and Lua, A. C. (2001). Kinetic study on pyrolytic process of oil-palm solid waste using two-step consecutive reaction model. *Biomass and Bioenergy,* 20**,** 223-233.

Haslenda, H. and Jamaludin, M. Z. (2011) Industry to Industry By-products Exchange Network towards zero waste in palm oil refining processes. *Resources, Conservation and Recycling,* **55,** 713-718.

Kathuria, V. and Nisar, A. K. (2002) Environmental Compliance versus Growth: Lessons from Malaysia's Regulations on Palm Oil Mills, *Economic and Political Weekly*, 37, 3993-3999.

Koh, L. P. and Wilcove, D. S. (2008) Is oil palm agriculture really destroying tropical biodiversity? *Conservation Letters*, 1, 60-64.

Laurance, W. F., Koh, L. P., Butler, R., Sodhi, N. S., Bradshaw, C. J. A., Neidel, J. D., Consunji, H. and Mateo Vega, J. (2010) Improving the Performance of the Roundtable on Sustainable Palm Oil for Nature Conservation. *Conservation Biology,* 24**,** 377-381.

Leão, R. R. d. C. C., Hamacher, S. and Oliveira, F. (2011). Optimization of biodiesel supply chains based on small farmers: A case study in Brazil. *Bioresource Technology,* 102, 8958-8963.

McCarthy, J. F., Gillespie, P. and Zen, Z. (2012) Swimming Upstream: Local Indonesian Production Networks in “Globalized” Palm Oil Production. *World Development,* 40, 555-569.

McCarthy, J. and Zen, Z. (2010) Regulating the Oil Palm Boom: Assessing the Effectiveness of Environmental Governance Approaches to Agro-industrial Pollution in Indonesia. *Law & Policy,* 32, 153-179.

Muttamara, S., Vigneswaran, S. and Shin, H.S. (1987) Palm Oil Mill Effluent Management in Thailand: A Preliminary Study, *Final report submitted to UNDP/FAO, Asian Institute of Technology, Bangkok.*

Office of Agricultural Economics (2012a) *Agricultural Statistics of Thailand 2012,* The Agricultural Cooperative Federation of Thailand, Thailand.

Office of Agricultural Economics (2012b) *Agricultural economics data of Thailand 2012,* The Agricultural Cooperative Federation of Thailand, Thailand.

S. Preechajarn. (2010) Thailand, Oil Palm Situation Field Trip. GAIN Report Number TH0114. USDA Foreign Agricultural Service, Global Agricultural Information Network. *http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Oil%20Palm%20Situation%20Field%20Trip_Bangkok_Thailand_8-9-2010.pdf.*

Rist, L., Feintrenie, L. and Levang, P. (2010) The livelihood impacts of oil palm: smallholders in Indonesia. *Biodiversity and Conservation*, 19, 1009-1024.

Sheil, D., Casson, A., Meijaard, E., van Noordwjik, M., Gaskell, J., Sunderland-Groves, J., Wertz, K. and Kanninen, M. (2009) *The impacts and opportunities of oil palm in Southeast Asia: What do we know and what do we need to know?,* Center for International Forestry Research (CIFOR), Bogor, Indonesia

Seegräf, M., May, D., Breuer, T. and Schukat, P. (2010) *Palm Oil – sustainability is possible! Promotion and certification of smallholders helps sustainable palm oil production*, publication on behalf of GTZ and Federal Ministry for the Environment, Nature Conservation and Nuclear Safety of the Federal Republic of Germany.

Suksa-ard, Chatchai and Morrakot Raweewan (In Press) Optimization of Supply and Demand Balance in Palm Oil Supply Chain, *Thammasat International Journal of Science and Technology*.

Sundaram, J. K., Chang, Y. T. and Khoo, K. J. (2004) *Deforesting Malaysia: the political economy and social ecology of agricultural expansion and commercial logging*, Zed Books in association with United Nations Research Institute for Social Development.

Univanich Palm Oil PCL (2011) *Palm Oil Practices in Thailand, Paper Presentated at: Thai Philippines Congress, 24-25 August 2011.*

Vermeulen, S. and Goad, N. (2006) *Towards Better Practice in Smallholder Palm Oil Production.* International Institute for Environment and Development.