MARKET SELECTION OF REFINED PALM OIL BASED ON BALANCING LOCAL DEMAND SATISFACTION AND EXPORTING

Chutchai Suksa-ard
School of Management Technology,
Sirindhorn International Institute of Technology, Thammasat University,
Pathum Thani, 12000, THAILAND
Email address: johotu@gmail.com

Morrakot Raweewan†
School of Management Technology,
Sirindhorn International Institute of Technology, Thammasat University,
Pathum Thani, 12000, THAILAND
+662-501-3505 ext 2115, Email: morrakot@siit.tu.ac.th

Abstract

This research investigates the issue of market selection to maximize palm oils' profit. When fresh fruit brunches (FFB) are pressed at crushing mills, the fruitlets give crude oils CPO and CPK that are sent to refineries to produce RPO, olein, and stearin. These oils are used in many products such as cooking oil, margarine, food, soap, animal feed, biodiesel, export, etc. The demand is increasing both worldwide and national because of biofuel initiative; however, available plantation area in Thailand is limited and the majority of farmer body is independent smallholders. Therefore, questions are left to be decided by policy makers. Given demands of oils in the country, how much land should be allocated for plantation in which region (north, northeast, central, or south); what is distribution network to transport from plantation to crushing mills, from crushing mills to refineries; which market of commodity products should be chosen; and how much oil to serve selected markets. A methodology is developed based on optimization model that will allow policy makers to answer these questions. A numerical experiment is conducted to illustrate the model and using IBM ILOG CPLEX to obtain the optimal solution. We found the model works well to provide information and suggestions for policy maker use in palm oil industry improvement.

Keywords: Palm oil supply chain management, Market selection, Demand satisfaction, Optimization

1. INTRODUCTION

FAO ranks Indonesia, Malaysia and Thailand the top three palm oil producing countries in the world. The increasing demand of palm oil has drawn large-scale plantation development to these Southeast Asian countries (Sundaram et al., 2004). Many plantations have their own mill (AOCS Lipid Library, 2013). However, unlike the major producing countries Malaysia and Indonesia dominated by large estates, plantations in Thailand are managed by independent smallholder farmers owning less than 50 ha. Fresh fruit brunches (FFB) are harvested by these smallholder farmers or collectors then transported to crushing mills nearby to minimize transportation cost. These farmers have no contracts or formal arrangement in planting and selling FFB to the mills. They act independently from crushing mills. This brings

† Corresponding author

challenges to palm oil supply chain management in Thailand. Chavananand (2011) talks about future overview and challenges in Thai palm oil supply chain. Even though smallholder farming helps distribute income to rural areas a question remain, how much land should be allocated to what region in the country to satisfy demands of domestic uses (ingredient of commodity product) and export, what distribution network should be assigned from plantations to mills to refineries. Research related to Thai smallholder farming in palm oil supply chain management is rear. Seegraf et al. (2011) studies smallholders plantation in Thailand and proposes optimization model to specifically manage harvesting practices and cooperation with mills and middlemen in order to increase the oil content of the fruits. Our research proposes tools to assist policy makers to make decision regarding the remaining questions mentioned previously.

2. PALM OIL PRODUCTION

Univanich Palm Oil PCL (2011) presents four factors driving growth of supply and demand in Thailand as following: 1) Domestic biodiesel policy creating demand, 2) Energy policies generating new investment opportunities, 3) Irrigation research increasing crop yields, and 4) Oil palm breeding improving drought tolerance. The same article also mentions that, in 2010, Thailand produces 1,288,000 tons of crude palm oil (CPO) of which is served in several industries: cooking oil 30%, margarine shortening 5%, biodiesel 35%, food products 17%, soap products 2%, animal feeds 2%, and exported 9%. Based on a composition chart of the palm fruit production processes in Muttamara et al. (1987), we present a supply chain of palm oil production in Figure 1.

On a supply side, plantation area in upstream supply chain produces FFB then transport to crushing mills and refinery in the midstream. A crushing mill produces crude palm oil (CPO) and crude palm kernel oil (CPK), and fat acid as by-product.

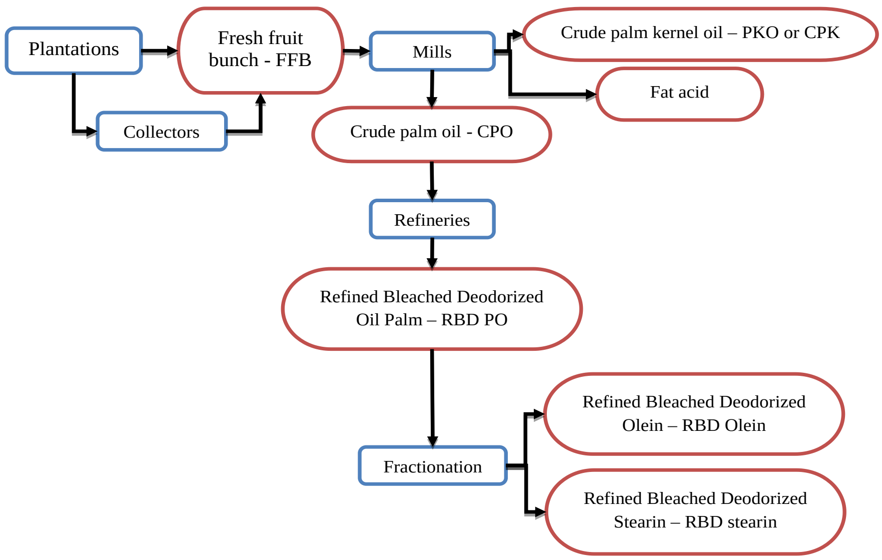

Figure 1: Palm oil production process from upstream to downstream supply chain. (Suksa-ard and Raweewan, in press)

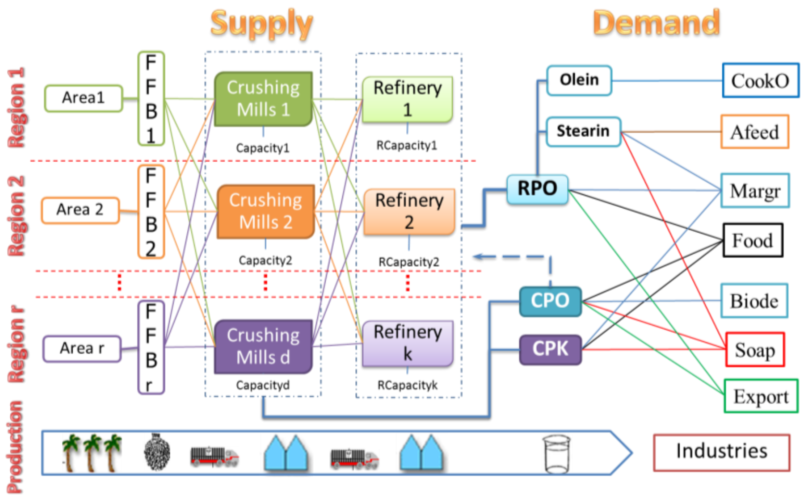

Figure 2: Distribution network from plantation to commodity product and export market. (Suksa-ard and Raweewan, in press)

Table 1: Mixture of palm oil products to produced one unit of commodity products. (Suksa-ard and Raweewan, in press)

Commodity Product	**Mixture to produce one unit of commodity product**					**Description**
	Olein	**Stearin**	**RPO**	**CPO**	**CPK**	
Cooking Oil	50%	-	-	-	-	50% of one unit of cooking oil is palm olein
Margarine	-	10%	60%	-	30%	10%, 60%, and 30% of magarine is stearin, RPO, and CPK, respectively
Food products	-	-	100%	100%	100%	Purely or mixed use RPO, CPO, or CPK
Soap products	-	40%	-	40%	10%	40%, 40%, and 10% of soap is stearin, CPO, and CPK, respectively
Animal Feed	-	10%	-	-	-	One unit of animal feed uses 10% of stearin.
Biodiesel	-	-	-	114%	-	100% of biodiesel will use CPO 114% as raw material to produce
Export	-	-	-	100%	100%	Use either CPO or CPK

A refinery produces refined bleached deodorized oil palm (RBD PO or RPO) from CPO then part of RPO will be used in fractionation to produce olein and stearin. These palm oil products, as supply side, will be sold to prospective industry to produce commodity product and export on the demand side. See Figure 2. These oils (CPO, CPK, RPO, palm olein, and palm stearin) are ingredient of commodity product. To produce one unit of each commodity product, these oils are used and mixed in different ratio presented in Table 1. The information is obtained from Department of Agricultural Extension of Thailand (2013).

3. MATHEMATICAL MODEL

The policy maker are consider as a government who response for overall palm oil production of country in each year. The palm oil products include CPO, CPK, RPO, olein, and stearin. The production of palm oil begin originate from FFB that planting in r regions. The total available mature area in region r is Q_r, yield rate of FFB per area unit in each region is y_r. All FFB produced in region r must be transported to crushing mills that located in d regions to produce CPO and CPK, with production cost of mc_d per unit of FFB. Transporting FFB from plantation in region r to crushing mill in region d have transportations cost, it cost fc_{rd} per unit of FFB. The total capacity of crushing mills in region d is M_d. To produce RPO, olein, and stearin, it needs CPO to be material in refinement process at refineries that located in k regions. Therefore, the CPO that produced in region d will be separated into two amounts, one kept as CPO to serving market demand and another transported to refinery in region k. The CPO transportation also has cost of cc_{dk} per unit of CPO. The production cost of RPO, olein, and stearin at refinery in region k is $rc_{i,k}$ per unit. The stearin is by product of olein process, therefore $rc_{stearin,k} = 0$ (Research institute, Suratthani Rajabhat University, 2012). The total refineries' capacity in region k is F_k. The percentage of extracted oil rate at crushing mills is $oe_{i,d}$ and oil refined rate at refineries is $op_{i,k}$. Each palm oil products is an ingredient of j commodity products (cooking oil, margarine, food, soap, animal feed, biodiesel, and export). The minimum demand of product j is min_j and the maximum demand is max_j. Given minimum and maximum demands of commodity products and export and different regional conditions of the size of harvesting area, yield, percentage of extracted oil, crushing mill capacity, refinery capacity, and cost, a mathematical model is proposed to assist policy makers to decide how much land should be allocated to which region in the country to satisfy demands of domestic uses (ingredient of commodity product) and export, what distribution network should be assigned from plantations to mills to refineries in order to maximize profit.

3.1 Parameters and Decision Variables

The discussed parameters, decision variables, set and index, and a proposed model are summarized as following.

Set and indices:

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

J = *set of commodity product and export market;*
{cooking, margarine, food, soap, animal-feed, biodiesel, export}

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*
F_k = *refinery's capacity (tons) per year at refinery in region k*
min_j = *minimum demand (tons) of commodity product j*
max_j = *maximum demand (tons) of commodity product j*
$oe_{i,d}$ = *oil extraction rate (%) of palm oil product i at mill in region d*
$op_{i,k}$ = *oil refined rate (%) of palm oil product i at refinery in region k*
b_r = *FFB purchasing cost (baht) per unit in region r*
fc_{rd} = *transportations cost (baht) per unit of FFB from plantation in region r to mill in region d*
cc_{dk} = *transportations cost (baht) per unit of CPO from mill in region d to refinery in region k*
mc_d = *mill cost (baht) per unit of FFB for produce CPO & CPK from FFB in region d*
$rc_{i,k}$ = *production cost (baht) of palm oil product i at refinery in region k*
$pp_{i,j}$ = *proportion (%) of palm oil product i to produce one unit of commodity product j*
pc_i = *selling price (baht) per unit of palm oil product i*

Decision variables:
q_r = *required land size (rais) for plantation in region r*
fp_{rd} = *amount of FFB (tons) transported from plantation region r to mill in region d*
cp_{dk} = *amount of CPO (tons) transported from mill in region d to refinery in region k*
cpo_d = *supply of CPO (tons) in region d*
cr_k = *amount of CPO (tons) for produce RPO in region k*
cf_k = *amount of CPO (tons) for produce olein and stearin in region k*
$S_{i,j}$ = *amount of palm oil product i (tons) to supply production of commodity product j*
C_j = *amount of commodity product j (tons) to supply the demand*

3.2 Mathematical Programming Model

The mathematical model to make the optimal decision on land allocation, satisfying demand, distribution network, and market selection to maximize profit is constructed as follows.

$$Maximize \sum_{i\in I}\sum_{j\in J} pc_i S_{i,j} - \sum_{r=1}^{R} b_r q_r y_r - \sum_{r=1}^{R}\sum_{d=1}^{R} fc_{rd} fp_{rd} - \sum_{d=1}^{R}\sum_{k=1}^{R} cc_{dk} cp_{dk} - \sum_{d=1}^{R}\sum_{r=1}^{R} mc_d fp_{rd} - \sum_{k=1}^{R}\left(rc_{olein,k} ole_k + \sum_{d} rc_k cp_{dk} \right) \qquad (1)$$

Subject to;

$$q_r \le Q_r \qquad (2)$$

$$q_r y_r \ge \sum_{d=1}^{R} fp_{rd}, \qquad r = 1, \dots, R \qquad (3)$$

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

$$oe_{CPO,d} \sum_{r=1}^{R} fp_{rd} \geq cpo_d + \sum_{k=1}^{R} cp_{dk}\,, \qquad d = 1, \dots, R \tag{5}$$

$$F_k \geq \sum_{d=1}^{R} cp_{dk}\,, \qquad k = 1, \dots, R \tag{6}$$

$$\sum_{d=1}^{R} cp_{dk} = cr_k + cf_k, \qquad k = 1, \dots, R \tag{7}$$

$$\sum_{j \in J} S_{CPO,j} \leq \sum_{d=1}^{R} cpo_d \tag{8}$$

$$\sum_{j \in J} S_{CPK,j} \leq \sum_{d=1}^{R} \sum_{r=1}^{R} oe_{CPK,d} fp_{rd} \tag{9}$$

$$\sum_{j \in J} S_{RPO,j} \leq \sum_{k=1}^{R} op_{RPO,k} cr_k \tag{10}$$

$$\sum_{j \in J} S_{olein,j} \leq \sum_{k=1}^{R} op_{olein,k} cf_k \tag{11}$$

$$\sum_{j \in J} S_{stearin,j} \leq \sum_{k=1}^{R} op_{stearin,k} cf_k \tag{12}$$

$$S_{i,j} = pp_{i,j} C_j, \qquad j \in \{cooking, margarine, soap, animalfeed, biodiesel\}, i \in I \tag{13}$$

$$C_j = \sum_{i} S_{i,j}\,, \qquad j \in \{food, export\}\,, i \in \{CPO, CPK, RPO\} \tag{14}$$

$$min_j \leq C_j \leq max_j \tag{15}$$

$$q_r \geq 0,\; fp_{rd} \geq 0,\; cp_{dk} \geq 0, cpo_d \geq 0,\; cr_k \geq 0,\; cf_k \geq 0\,,\; S_{i,j} \geq 0\,,\; C_j \geq 0 \tag{16}$$

Equation (1) represents the objective function, which aim to maximize profit of selling palm oil products to satisfy commodity products' demand. The profit is the difference between total revenue from selling palm oil products and total costs, including total FFB purchasing cost, total transportation costs of FFB and CPO, total production cost of palm oil product (CPO, CPK, RPO, olein, and stearin) at crushing mill and refinery cost. 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) explains that CPO produced from FFB at crushing mills in region d is separated into two amounts – one is kept as CPO and the other is transported to refineries in region k. Constraint (6) limits amount of CPO transported from mill in every regions d to refinery in region k not to exceed capacity of refinery in region k. Constraint (7) states that amount of CPO for produce RPO (cr_k) and CPO for produce Olein & Stearin (cf_k) at refinery in region k will not exceed total amount of CPO transported from every regions d to refinery in region k. Constraint (8), (9), (10), (11), and (12) state that the total amount of each palm oil product i supplying the production of commodity product j ($S_{i,j}$) cannot exceed the amount of feed stock of each palm oil product i which is the total of each palm oil product i were produced from all region. Constraint (13) states that amount of palm oil product i to supply the demand of commodity product j (except food and export) is the amount of that commodity product j to supply the market demand multiplied by the mixture proportion of palm oil products from Table 1. Constraint (14) states that the amount of palm oil for supply food production and export demand is gathered from CPO, CPK, and RPO which available for the industries' market. Constraint (15) states that the supply commodity product j should satisfy between minimum demand and maximum demand of that commodity product. Constraint (16) is non-negativity condition.

4. NUMERICAL EXAMPLE

4.1 Numerical Input

The values of parameters in this study are collected from Thai palm oil industry. Information is collected from directed interview and various secondary data sources in Thailand. Only commodity product demand is estimated by author. In the following examples based on Chavananand (2011), the plantation zone is located in northern, northeastern, central, and southern zones of Thailand; crushing mills exist in only three zones (northeastern, central, and southern zone); and refineries are in two zones (central and southern zone). Input parameters of plantation, crushing mills, and refineries in four zones are shown in Table 2.

We also estimated the domestic commodity demand and export for use in the model as show in Table 3. Each commodity products has been set minimum and maximum demand that mean each demand have to be served at least in minimum demand level. The export demand is not required the minimum demand, the priority is to serve domestic demand before export. FFB purchasing price in Table 2 is set by government policy and selling prices in Table 4 using monthly base-price of palm oil products on October, 2012 (Office of agricultural Economic, 2012b) as market price. Transportation cost estimated on average cost for 21-ton trucks from plantations r to mills d (fc_{rd}) and from mill d to refineries k (cc_{dk}) in unit of baht per ton, used cost rate from DX Innovation Co., Ltd as show in Table 5.

Table 2: 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' 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%
Mills' cost[3]	Baht/ton	N/A	500	500	500
Refineries' Cap.[4]	ton CPO/year	N/A	N/A	1,975,500	90,000
Refined rate of RPO[5]	% of CPO	N/A	N/A	93%	93%
Refined rate of Olein[5]	% of CPO	N/A	N/A	66%	66%
Refined rate of Stearin[5]	% of CPO	N/A	N/A	29%	29%
Refineries' cost[5]	Baht/ton CPO	N/A	N/A	1,500	1,500
Olein production cost[5]	Baht/ton olein	N/A	N/A	2,500	2,500
Stearin production cost[5]	Baht/ton stearin	N/A	N/A	0	0

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 3: Commodity demand (ton/year)

Demand	**Cooking Oil**	**Margarine**	**Food Industry**	**Soap Industry**	**Animal Feed**	**Biodiesel**	**Export**
Minimum[1]	500,000	100,000	100,000	400,000	50,000	500,000	0
Maximum[1]	1,000,000	300,000	200,000	800,000	100,000	1,650,000	820,000

[1]Estimated by author.

Table 4: Selling price of palm oil product (baht/ton)

CPO	**CPK**	**RPO**	**Olein**	**Stearin**
27,810	27,870	28,530	28,950	26,580

Table 5: Transportation cost (baht/ton)

From \ To	North (1)	Northeast (2)	Central (3)	South (4)
North (1)	N/A	372	384	652
Northeast (2)	N/A	182	391	712
Central (3)	N/A	391	174	425
South (4)	N/A	712	425	175

N/A = no mills in the region

4.2 Result

The optimization models were written in IBM ILOG CPLEX. Numerical result of discussed in formation shows the optimal supply chain and following result. Table 6 shows that the maximum profit is 12,354.460 million baht per year or gain profit 18%. The largest cost is FFB purchasing cost that contributed 67.6%. Transportation cost, mills cost, and refineries cost contributed 3.2%, 8.2%, and 3.0% respectively. Table 7 shows the demand of cooking oil and biodiesel are satisfied in between minimum demand and maximum demand while demand of margarine, soap, and animal feed are only met at the minimum level and demand of food and export are met at the maximum level. The calculation of serving unit of commodity products by using palm oil product is referred to the mixture rate in Table1. The total supply of CPO, CPK, RPO, olein, and stearin are 1,257.584 kilotons, 566.337 kilotons, 60 kilotons, 398.276 kilotons, and 175 kilotons respectively. Table 8 shows production region of each palm oil products and required plantation area. Plantation area in every region is fully used to produce FFB to served palm oil production and all palm oil products is used to serve the commodity product demand. This shows that current plantation area is not enough to satisfy the increasing demand in the future.

Table 6: Maximum profit and percentage of profit and cost

Revenue & Cost	Million Baht	Percent
Total Revenue	68,650.640	100.0%
Total FFB purchasing cost	46,439.703	67.6%
Total FFB transportation cost	1,983.950	2.9%
Total CPO transportation cost	211.512	0.3%
Total Mills cost	5,663.378	8.2%
Total Refineries cost	1,997.637	3.0%
Total Profit (Maximum)	**12,354.460**	**18.0%**

Table 7: Supply of palm oil product to commodity product and supply quantity of commodity products (kton)

Commodity Products	Supply of palm oil product to commodity product					Supply quantity
	CPO	CPK	RPO	Olein	Stearin	(Min / **Supply** / Max)
Cooking Oil	0	0	0	398.276	0	500 / **796.552** / 1,000
Margarine	0	30.000	60.000	0	10.000	100 / **100** / 300
Food	200.000	0	0	0	0	100 / **200** /200
Soap	160.000	40.000	0	0	160.000	400 / **400** / 800
Animal Feed	0	0	0	0	5.000	50 / **50** /100
Biodiesel	573.922	0	0	0	0	500 / **503.440** / 1,650
Export	323.662	496.337	0	0	0	0 / **820** / 820
Total	**1,257.584**	**566.337**	**60.000**	**398.276**	**175.000**	

Table 8: Required area and amount of palm oil production by region.

Regions	Required area(rais)	Amount of palm oil production (kton)					
		FFB	CPO	CPK	RPO	Olein	Stearin
North (1)	18,326	10.556	N/A	N/A	N/A	N/A	N/A
Northeast (2)	75,598	100.848	0	5.042	N/A	N/A	N/A
Central (3)	735,127	1,144.593	0	57.757	0	381.457	167.610
South (4)	3,446,530	10,070.761	1,257.584	503.538	60.000	16.819	7.390
Total	**4,275,581**	**11,326.758**	**1,257.584**	**566.337**	**60.000**	**398.276**	**175.000**

Table 9: Amount of FFB and CPO distributed from plantations to crushing mills and from crushing mills to refineries in each region.

To / From	Transportation of FFB				Transportation of CPO			
	North (1)	North-east (2)	Central (3)	South (4)	North (1)	North-east(2)	Central (3)	South (4)
North (1)	N/A	0	10.556	0	N/A	N/A	N/A	N/A
Northeast (2)	N/A	100.848	0	0	N/A	N/A	17.144	0
Central (3)	N/A	0	1,144.593	0	N/A	N/A	196.375	0
South (4)	N/A	0	0	10,070.761	N/A	N/A	364.445	90.000
Total	**N/A**	**100.848**	**1,155.149**	**10,070.761**	**N/A**	**N/A**	**577.964**	**90.000**

Table 9 show transportation networks and amount of FFB and CPO distributed form plantation to crushing mills and from crushing mills to refinery. FFB 10.556 kilotons from plantation in northern region and 1,144.593 kilotons in central region are transported to crushing mills in the central regions. 100.848 kilotons of FFB harvested in the northeastern region is sent to crushing mills in the same region. FFB in the southern zone 10,070.761 kilotons is transported to the same region. All FFB is use to for CPO and CPK production at crushing mills. CPOs from three zones is sent to be refined in the next process. One amount of CPO is kept to serve CPO demand; the rest is transported to refineries to produce refined oils (RPO, olein, and stearin). The amount of 17.144 kilotons of CPO in the northern region, 196.375 kilotons of CPO in the central region, and 364.445 kilotons of CPO in southern region are sent to refinery in central region while another 90 kilotons of CPO in southern region is sent to refinery in the same region. This shows that the refinery in southern region have not enough capacity to handle amount of CPO for produce refined oil in the same region while refinery in southern region and crushing mills in every region have residual capacity to handle palm oil production. The overall discussed result is summarized and illustrated in Figure 3.

This numerical example shows that the current palm oil supply chain situation can only handle the current commodity demand and export level. If these demand increased, there is not enough plantation area to supply FFB. The current crushing mills' utilization is only 56% that mean we have enough crushing mills' capacity to handle FFB in CPO and CPK production process. The largest of CPO production is in southern region, but the refinery's capacity to handle the amount of CPO for refined oil production in the same region is not enough. Therefore the CPO for refined oil production has to transport to refineries in central region that increase the CPO transportation cost.

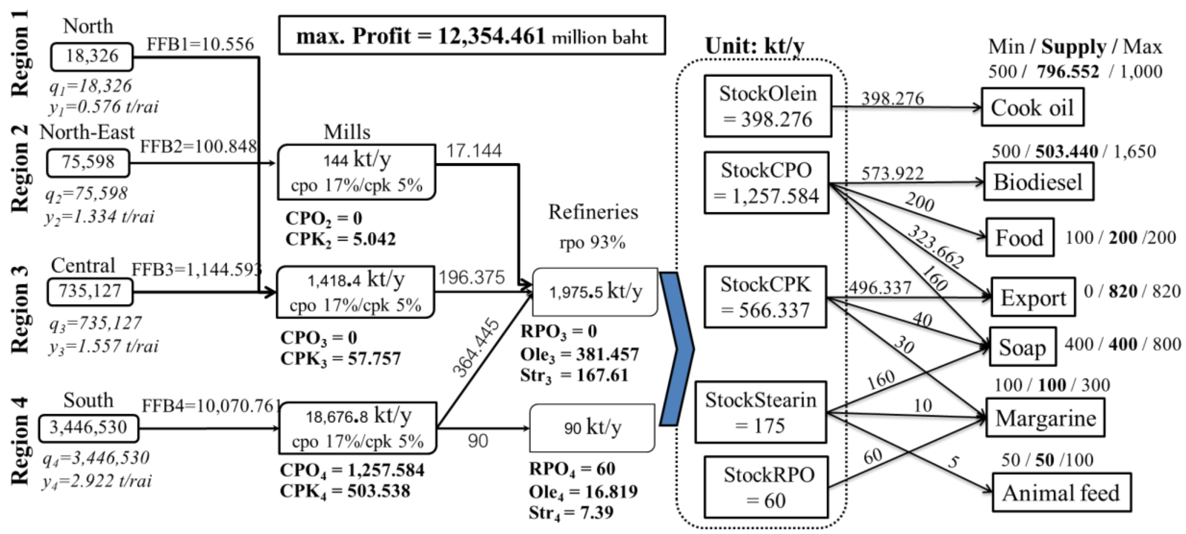

Figure 3: Numerical output; profit & distribution from plantation to mills to refineries to commodity markets and export (kiloton).

5. CONCLUSION AND FUTURE RESEARCH

A methodology has been proposed that policy makers need quantitative tools to assist in making decision regarding plantation allocation, market allocation, and distribution network planning. This research explores such tools determining how much land should be allocated to what region in the country to satisfy demands of domestic uses (ingredient of commodity product) and export, what distribution network should be assigned from plantations to mills to refineries in order to maximize profit in the management. Our future work will explore when stock is utilized in distribution network from mills to refineries and from refineries to commodity market.

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