NUMERICAL STUDY FOR THAILAND: MATHEMATICAL MODEL OF PRODUCTION AND LOGISTIC PLANNING FOR SUGARCANES USED IN BIOFUEL PRODUCTION

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Abstract

Thailand uses sugarcane as the main crop to produce ethanol to mix with gasoline to produce bio-fuel such as E-20, a fuel mixture which contains 20% of ethanol and 80% of gasoline. At present, the fossil fuel price is continually rising and the supply is limited, especially in Thailand. Renewable fuel is an excellent alternative to prevent a dependency on this fuel. Moreover, the production of the combustion of ethanol emits significantly less pollutants to an environment compared to fossil fuels. In this research, we study the production planning for sugarcane used as feedstock to produce bio-fuel, and optimal logistics solutions for distributing the crop to the processing plants in Thailand. The main objective of this research is to find a mathematical model to find the optimal decisions on the planning of sugarcane production, the planning of logistics minimizing the transportation costs from the planting areas to the processing plants and the planning of additional processing plant capacity and locations. The model is coded with IBM ILOG CPLEX and numerical experiment is conducted to test the model. We collected the secondary data to develop case study for Thailand. The result of model will help provide the guideline to Thai government, companies and farmers on how to plan the crop production in the future.

Keywords: Mathematical Model, Sugarcane, Production, Logistics, Capacity Planning

1. INTRODUCTION

The world economy has been largely depending on fossil energy resources such as natural gas, oil, coal, and uranium. Fossil fuels have been widely used as a source of energy throughout the world. Huge amount of fossil fuels are everyday and also generating a great amount of greenhouse gases (GHG), which are responsible for the accelerating global warming and its catastrophic consequences. The supply of these fuels is physically limited, and their use threatens our health and environment. Moreover, burning fossil fuel releases toxics to the environment, and particulates of them can cause problems to human such as cancer, brain and nerve damage, and breathing problems. The toxic stew released by combusting hydrocarbons pollutes the air and water can causes acid rain and smog. Conversely, oil is necessary for almost all machines to move and we live in a current era where oil is necessary to produce, transport food, for movement of vehicles, airplanes etc. Oil is the most important ingredient for our lives, for industry, for economic development and for our prosperity. Unfortunately, we are facing a global energy crisis with natural reserves being depleted fast due to over consumption and now energy crisis is a major concern in most part of the world.

Due to the fact that the fossil fuel price is continually rising, renewable fuels are an excellent alternative to prevent a dependency on this fuel. E20 is a fuel mixture which blends 20 percent ethanol, a renewable source of energy extracted from plants, with gasoline, that can be used in internal combustion engines of most modern automobiles without need for any adjustment on the engine or fuel system. The production or the combustion of ethanol emits green-house gases or poisonous significantly lower than fossil fuels do.

Currently, Thailand is facing a serious problem with the reliance on oil imports from other countries, approximately 80% of crude oil, gasoline, and diesel being imported. The government is searching for ways to fix this problem and to improve national energy security by reducing demand for foreign oil. Therefore, the government has set new 10-year Alternative Energy Development Plan (2012-2021) which was approved by the cabinet on December 27, 2011 to solve oil import problem and to strengthen domestic energy security (Cheokul, 2012). Ethanol is one of the promising technologies that could help the country work toward the goal of energy security. Figure 1 shows Thailand's ethanol production target during 2012-2021from the New 10-Year Development Plan. There are several different ingredients to produce E20, for example, sugarcane and cassava; however for this research, the alternative we have chosen to study is sugarcane.

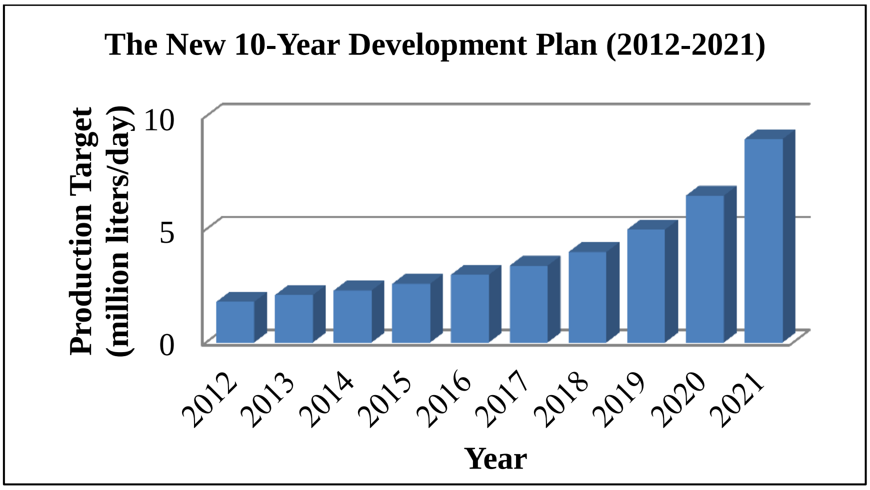


Figure 1: Thailand's ethanol production target during 2012-2021

Previously, the government has set the 15-year plan (2008-2022) to manage with the problems but it has fallen short of achieving its short-term targets, particularly in ethanol consumption. The new plan set the ethanol consumption target 9.0 million liters per day by 2021. Ethanol production will increase to 1.9 million liters per day in 2012 and to 2.1 million liters per day in 2013, as compared to 1.4 million liters per day in 2011. Ethanol exports are expected to increase to 300-350 million liters in 2012-2013, or 45% of total ethanol production, as compared to 27% in 2011. Thus, to ensure that the significantly increasing demand of E-20 in the next 10-year will be satisfied, the supply of sugarcane will have to increase as well as match properly with the upcoming demand.

The main objective of this research is to form a mathematical model to find the additional capacity for sugarcane production planning of existing plants to satisfy the 10 year predicted demand while minimizing the cost of production, transportation and facilities. To achieve the optimal solution, we code a model of sugarcane production planning in the IBM ILOG CPLEX version 12.1. Furthermore, this model could provide directions for future research and might be applied in other related fields, for example, efficient water management for sustainable agriculture.

We organize the remaining of this paper as following. In section 3, the assumptions and mathematical model of sugarcane production planning is discussed. In section 4, the model is tested and numerical results are investigated. In section 5, we conclude the research and provide the direction of future research.

2. DATA COLLECTION

2.1 Sugarcane planting areas

For sugarcane planting area, there are total 47 provinces that planted sugarcane in 4 regions of Thailand which are North, Central, Northeast, and East region. Table 1-4 show the planting areas, average production per rai and total production in all regions (Office of The Cane and Sugar Board, 2011). Lastly, total area that planted sugarcane in Thailand is approximately 8,461,256 rai. Please note that 1 “rai” is equal to 0.0016 km2.

Table 1: Sugarcane Planting Area in North Region

North Region

No.	Province	Planting Area (Rai)	Average Production (Ton/Rai)	Total Production (Ton)
1	Lampang	33,637	10.92	367,313
2	Phrae	7,342	11.77	86,410
3	Uttaradit	57,550	11.90	684,842
4	Sukhothai	181,695	11.95	2,171,254
5	Tak	6,798	12.36	84,018
6	Kamphaeng Phet	466,655	12.32	5,749,192
7	Nakhon Sawan	515,951	12.63	6,516,463
8	Phitsanulok	92,054	12.15	1,118,455
9	Phichit	53,967	12.36	667,028
10	Phetchabun	304,650	12.14	3,698,452
	Total	**1,720,299**	**12.29**	**21,143,427**

Table 2: Sugarcane Planting Area in Central Region

Central Region

No.	Province	Planting Area (Rai)	Average Production (Ton)	Total Production (Ton)
11	Uthai Thani	296,672	12.20	3,619,398
12	Chai Nat	95,701	12.25	1,172,340
13	Sing Buri	76,727	12.28	942,208
14	Lop Buri	540,155	12.18	6,579,088
15	Saraburi	97,626	12.32	1,202,752
16	Ang Thong	17,841	12.56	224,078
17	Suphan Buri	504,975	12.29	6,206,147
18	Kanchanaburi	581,719	12.25	7,126,058
19	Nakhon Pathom	84,396	12.36	1,043,139
20	Ratchaburi	170,198	12.23	2,081,521
21	Phetchaburi	32,506	11.94	388,126
22	Prachuap KhiriKhan	48,913	11.65	569,836
	Total	**2,547,429**	**12.23**	**31,154,691**

Table 3: Sugarcane Planting Area in Northeast Region

Northeast Region

No.	Province	Planting Area (Rai)	Average Production (Ton)	Total Production (Ton)
23	Loei	128,334	11.49	1,471,986
24	Nong Bua Lam Phu	137,264	12.25	1,681,482
25	Udon Thani	586,859	11.10	6,514,135
26	Nong Khai	31,817	11.18	355,714
27	Sakon Nakhon	61,888	11.19	692,527
28	Nakhon Phanom	8,584	11.09	95,198
29	Chaiyaphum	470,335	11.30	5,314,788
30	Khon Kaen	563,837	11.21	6,320,613
31	Maha Sarakham	138,573	11.18	1,549,243
32	Roi Et	85,043	10.90	926,967
33	Kalasin	300,811	11.26	3,387,128
34	Mukdahan	145,708	11.47	1,671,272
35	Amnat Charoen	28,920	11.09	320,717
36	Yasothon	27,333	11.30	308,862
37	Nakhon Ratchasima	560,413	11.22	6,287,834
38	Buri Ram	183,384	11.34	2,079,575
39	Surin	193,421	11.11	2,148,905
40	Si Sa Ket	6,104	11.10	67,752
41	Ubon Ratchathani	11,258	11.17	125,752
	Total	**3,669,886**	**11.26**	**41,320,450**

Table 4: Sugarcane Planting Area in East Region

East Region

No.	Province	Planting Area (Rai)	Average Production (Ton)	Total Production (Ton)
42	Prachin Buri	24,633	11.00	270,959
43	Sa Kaeo	252,713	10.89	2,752,040
44	Chachoengsao	63,703	11.02	702,007
45	Chon Buri	149,463	10.90	1,629,152
46	Rayong	11,174	10.72	119,781
47	Chanthaburi	21,956	10.99	241,292
	Total	**523,642**	**10.91**	**5,715,231**

2.2. Plant Capacity

For plant capacity, only sugarcane ethanol production is considered in this study. The totals of 23 sugarcane ethanol plants were located in 18 provinces. The proportion of feedstock to the plant in each region will be 16.50% to north region, 32.63% to central region, 5.29% to east and 45.56% to northeast plant. Department of Alternative Energy Development and Efficiency (2012) collected the ethanol plants for all Thailand regions as shown in Table 5-8. Research and Service on Energy Center (2006) stated that one ton of molasses can produce 260 liters of ethanol. Also, one ton of sugar can generate 50-60 kg. of molasses (Thai Chemical & Engineering, n.d.) Using these two numbers, we can calculate the amount of sugarcane to produce to satisfy the output of ethanol (shown in Table 5-8).

Table 5: Ethanol Plants in North Region

North Region

No.	Plant	Site	Raw Material	Production Capacity as Permitted (Liter)	Input (Ton)
					Sugarcane
1	Ekaratpathana Co.ltd	Nakhon Sawan	Molasses	200,000	12,834
2	Thai Rung Rueng Energy Co.ltd	Phetchabun	Molasses/Sugarcane	200,000	7,840
3	Thai Sugar Ethanol Co.ltd	Kamphaeng Phet	Cassava/Sugarcane	200,000	1,429
4	Mae Sawd Clean Energy Co.ltd	Tak	Sugarcane	200,000	2,858
Total				1,340,000	24,961

Table 6: Ethanol Plants in Central Region

Central Region

No.	Plant	Site	Raw Material	Production Capacity as Permitted (Liter)	Input (Ton)
					Sugarcane
1	Pawn Wilai International Group Trading Co.ltd	Ayutthaya	Molasses	25,000	1,603
2	Thai Agro Energy Plc	Suphan Buri	Molasses	150,000	9,618
3	Thai Alcohol Plc	Nakhon Pathom	Molasses	200,000	12,834
4	Thai Sugar Ethanol Co.ltd, 1st Phase Thai Sugar Ethanol Co.ltd, 2nd Phase	Kanchanaburi Kanchanaburi	Molasses/Sugarcane Molasses/Sugarcane	100,000 100,000	3,920 3,920
5	Thai Rung Rueng Energy Co.ltd, 1st Phase Thai Rung Rueng Energy Co.ltd, 2nd Phase	Saraburi Saraburi	Molasses/Sugarcane Molasses/Sugarcane	120,000 80,000	4,704 3,136
6	Ratchaburi Ethanol Co.ltd	Ratchaburi	Molasses/Cassava	150,000	4,809
7	Khonkaen Alcohol Co.ltd	Kanchanaburi	Molasses/Sugarcane/ Cassava	150,000	4,809
Total				**1,275,000**	**49,353**

Table 7: Ethanol Plants in East Region

East Region

No.	Plant	Site	Raw Material	Production Capacity as Permitted (Liter)	Input (Ton)
					Sugarcane
1	ES Power Co.ltd	Sa Kaeo	Molasses/Cassava	150,000	4,809
2	Khon Kaen Alcohol Co.ltd	Chonburi	Molasses/Sugarcane/ Cassava	100,000	3,206
Total				**4,200,000**	**8,015**

Table 8: Ethanol Plants in Northeast Region

Northeast Region

No.	Plant	Site	Raw Material	Production Capacity as Permitted (Liter)	Input (Ton)
					Sugarcane
1	Petro Green Co.,ltd	Kalasin	Molasses/Sugarcane	200,000	7,841
2	Khon Kaen Alcohol Co.,ltd	Khon Kaen	Molasses/Sugarcane	150,000	5,880
3	Petro Green Co.,ltd, 1st Phase Petro Green Co.,ltd, 2nd Phase	Chaiyaphum Chaiyaphum	Molasses/Sugarcane Molasses/Sugarcane	200,000 200,000	7,841 7,841
4	KI Ethanol Co.ltd	Nakhon Ratchasima	Molasses/Sugarcane	100,000	3,920
5	Angwien Industry Co.ltd	Nakhon Ratchasima	Molasses/Sugarcane	160,000	6,272
6	Erawan Ethanol Co.ltd	Nong Bua Lam Phu	Molasses/Sugarcane	200,000	7,841
7	Saharueng Ethanol Co.ltd	Mukdahan	Molasses	100,000	6,412
8	Esarn Sugar Industry Co.ltd	Kalasin	Molasses/Cassava	120,000	3,847
9	NY Ethanol Co.ltd	Nakhon Ratchasima	Molasses/Cassava	150,000	4,809
10	Buriram Ethanol Co.ltd	Buri Ram	Molasses/Cassava	200,000	6,412
Total				**5,480,000**	**68,916**

2.3 Transportation Cost

In this study, we used truck mode as a transportation choice. For transportation cost, the data observed from the Office of Transport and Traffic Policy and Planning, Ministry of Transport, was stated equal to 1.72 baht per ton per kilometer (Office of Transport and Traffic Policy and Planning, n.d.).

2.4. Distance between plant locations and planting areas

Distances between plant location and the planting area (specified by provinces) are from the web site of Department of Highways. In this study, there are 18 plant locations and 47 planting area.

2.5. Cost of planting sugarcane

Sugarcane once planted, can be reproduced for three times which called the first year, second year, and third year sugarcane, respectively. However, the annual cost and production rate vary each year. The cost and production rate of sugarcane plantation are listed in Table 9 (Pongwanich-Anan, 2009). To use the costs in planning over the period of ten years, we calculate the present value of costs using a discount rate of 7% as used in Khangrit (n.d.).

Table 9: Cost of Planting Sugarcane per Rai and Production per Rai

Cost (THB/Rai)	First Year	Second Year	Third Year	Average
Variable Costs	4,863.83	3,105.55	2,611.65	3,527.01
Labor Costs	1,512.90	923.07	688.29	1,041.42
Material Costs	3,050.15	1951.05	1,721.06	2,240.75
Transportation Costs	133.43	116.81	105.66	118.63
Miscellaneous Costs	421.98	114.62	96.65	126.21
Fixed Costs	1,147.09	1,147.09	1,147.09	1,147.09
Total Cost per Rai	**6,559.13**	**4,374.62**	**3,901.08**	**4,674.10**
Production (Tons/Rai)	11.12	9.73	8.80	9.88

2.6. Cost of Capital Investment of Ethanol Plant

We gathered the data from the real cases of the ethanol plants in Thailand. We investigated from 4 plants which are Petro Green Co.,Ltd, Phu Keaw Ethanol Plant, Dan Chang Ethanol Plant, and Kalasin Ethanol Plant. The costs, capacity, and feedstock required are shown in Table 10.

Table 10: Sugarcane-based Ethanol Plant Investment Cost

Name	Capacity (Liter/Day)	Investment Cost (Baht)	Sugarcane Required per Day (Ton)	Investment Cost per Ton (Baht)
Petro Green Co.,Ltd	350,000	2,000,000,000	5,005	399,600.39
Phu Keaw Ethanol Plant	230,000	730,000,000	3,289	221,951.96
Dan Chang Ethanol Plant	230,000	730,000,000	3,289	221,951.96
Kalasin Ethanol Plant	230,000	730,000,000	3,289	221,951.96
			Average	**266,364.06**

Source: Petro Green Co.,Ltd, Mite Phol Group Co.,Ltd

3. MATHEMATICAL MODEL

We consider a supply chain consisting of sugarcane plantations and processing plants. The decision maker tries to minimize total cost of all the production, transportation and capacity expansion costs of sugarcane supply chain. In this case, we have three indexes j, k and t which represent land, plant and time period respectively. In this study, there are in total of j areas to plant sugarcane. In each area the size of land could be different. Each piece of land can be used to plant sugarcane independently with different starting point. Production rate of land j decreases over time as sugarcane age increases. Hence, typically sugarcanes were restarted planting every three years. This model minimizes the total cost consisting of three main costs which are production cost, transportation cost and plant expanding cost. Production cost is determined by the net present value of total cost per rai from all periods. In each period, the total production of sugarcane from all areas must equal to or exceed the total demand of sugarcane. All sugarcane produced at land j must be matched to sugarcane ethanol processing plants. There is a transportation cost to transport sugarcane from the planting area to the processing plant. The cost of transportation depends on origin (or land *j*) to destination (or plant *k*). The all of parameters and decision variables are summarized below.

Sets:

$Max\ number\ of\ land = \overline{J}$

$Max\ number\ of\ plant = \overline{K}$

$Max\ number\ of\ period = \overline{T}$

$J = \left\{1, 2, ..., \overline{J}\right\}$

$K = \left\{1, 2, ..., \overline{K}\right\}$

$T = \left\{1, 2, ..., \overline{T}\right\}$

Parameters:

$\alpha = \frac{1}{(1+r)}\ where\ r\ is\ the\ cost\ of\ capital$

$N_j = Size\ of\ land\ (rai)$

$prodcost_{j,t} = Net\ present\ value\ (discounted\ to\ year\ 0)\ of\ total\ production\ cost\ per\ rai\ from\ all\ periods\ if\ starting\ planting\ in\ period\ t\ at\ land\ j$

$trancost = transportation\ cost\ to\ transport\ sugarcane\ per\ ton\ per\ km$

$plantcost = plant\ capacity\ expansion\ cost\ per\ ton\ of\ sugarcane\ input$

$D_t = Demand\ of\ Sugarcane\ (tons)\ in\ period\ t$

$o_l = Tons\ of\ output\ of\ sugarcane\ per\ rai\ when\ the\ land\ has\ started\ planting\ for\ l\ years\ (Note\ that\ o_l = o_{\tau+l} = o_{2\tau+l})$

$Ec_k = Existing\ capacity\ of\ plant\ k\ (tons)\ of\ sugarcane\ input$

$d_{j,k} = Distance\ (km.)\ from\ land\ j\ to\ plant\ k$

$\underline{c} = Minimum\ size\ of\ capacity\ to\ expand\ (tons)$

$\overline{c} = Maximum\ size\ of\ capacity\ to\ expand\ (tons)$

Decision Variables

$ap_{j,t} = Average\ production\ (tons)\ from\ new\ land\ j\ in\ period\ t$

$s_{j,k,t} = Quantity\ of\ sugarcane\ (tons)\ transported\ from\ land\ j\ to\ plant\ k\ in\ period\ t$

$c_{k,t} = Additional\ Capacity\ of\ Plant\ k\ (tons)\ installed\ in\ period\ t$

$p_{j,t} = New\ production\ of\ sugarcane\ (tons)\ from\ land\ j\ in\ period\ t$

$cp_t = Current\ production\ of\ sugarcane\ (tons)\ in\ period\ t$

$x_{k,t} = 1\ if\ plant\ k\ installs\ new\ capacity\ period\ t;\ 0\ otherwise$

$y_{j,t} = 1\ if\ land\ j\ starts\ planting\ in\ period\ t;\ 0\ otherwise$

$$Minimize\ Total\ Cost = \sum_{t=1}^{T}\sum_{j=1}^{J} N_j \times prodcost_{j,t} \times y_{j,t} + \sum_{t=1}^{T}\sum_{j=1}^{J}\sum_{k=1}^{K} \alpha^t \times \left(trancost \times d_{j,k} \times s_{j,k,t}\right) \quad (1)$$

$$+\sum_{t=1}^{T}\sum_{k=1}^{K} \alpha^t \times plantcost \times c_{k,t}$$

$Subject\ to:$

$$p_{j,t} = \sum_{l \le t} y_{j,l} o_{t-l+1}, \forall\ j \in J\ and\ t \in T \quad (2)$$

$$\sum_{t=1}^{T} y_{j,t} \le 1, \forall\ j \in J \quad (3)$$

$$cp_{j,t} \le N_j \times ap_{j,t}, \forall\ j \in J\ and\ t \in T \quad (4)$$

$$\sum_{j=1}^{J} N_j p_{j,t} + cp_{j,t} \ge D_t, \forall\ t \in T \quad (5)$$

$$\sum_{k \in K} s_{j,k,t} = N_j p_{j,t} + cp_{j,t}, \forall\ j \in J\ and\ t \in T \quad (6)$$

$$\sum_{j \in J} s_{j,k,t} \le Ec_k + \sum_{l=1}^{t} c_{k,l}, \forall\ k \in K\ and\ t \in T \quad (7)$$

$$x_{k,t} \times \underline{c} \le\ c_{k,t} \le x_{k,t} \times \bar{c}, \forall\ j \in J\ and\ t \in T \quad (8)$$

$$cp_{j,t}, p_{j,t} \ge 0, \forall\ j \in J\ and\ t \in T \quad (9)$$

$$c_{k,t} \ge 0, \forall\ k \in K\ and\ t \in T \quad (10)$$

$$s_{j,k,t} \ge 0, \forall\ j \in J, k \in K\ and\ t \in T \quad (11)$$

$$x_{k,t} \in \{0,1\}, \forall\ k \in K\ and\ t \in T \quad (12)$$

$$y_{j,t} \in \{0,1\}, \forall\ j \in J\ and\ t \in T \quad (13)$$

Equation (1) is the objective function to be minimized. It is the total cost which is the sum of production cost, the transportation cost and plant expansion cost. Equation (2) sets up the production rate each period after land j starts planting. Equation (3) only allows land j to start planting once. Equation (4) limits the amount of current production decision to be fewer than or equal the average production capacity in land j. Equation (5) states that the supply from new land and the supply from current land must exceed the demand. Equation (6) equates the quantities sent out to all plants and the total supply from land j. Equation (7) limits the quantities received at plant k to be fewer than the existing capacity plus the accumulated additional capacity installed. Equation (8) limits the additional capacity installed to be within lower bound and upper bound. Equations (9)-(13) state the types of decision variables.

Using the model plugged in by the secondary data collected, we have the guideline for Thailand in terms of production, logistics and capacity planning.

4. RESULTS

4.1 Sugarcane Supply and Plant Capacity

In this section, we will discuss about the production planning for sugarcane which used as main raw materials for producing ethanol in Thailand. This problem is all solved by IBM ILOG CPLEX version 12.1 to find the optimal planning for sugarcane. Figures 2-5 show the supply of sugarcane during 2012-2021. According to the figures, the total supply of sugarcane during year 2012 until 2017 is still able to satisfy all the demand. However, sugarcane demand increases dramatically after the year 2017; hence additional supply is required to match with the demand until the end of the period.

Figure 2: sugarcane supply during 2012-2021 North Region

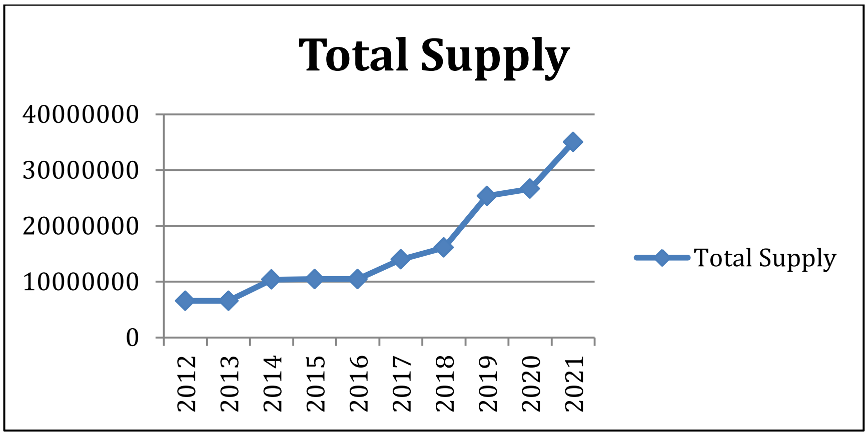


Figure 3: sugarcane supply during 2012-2021 Central Region

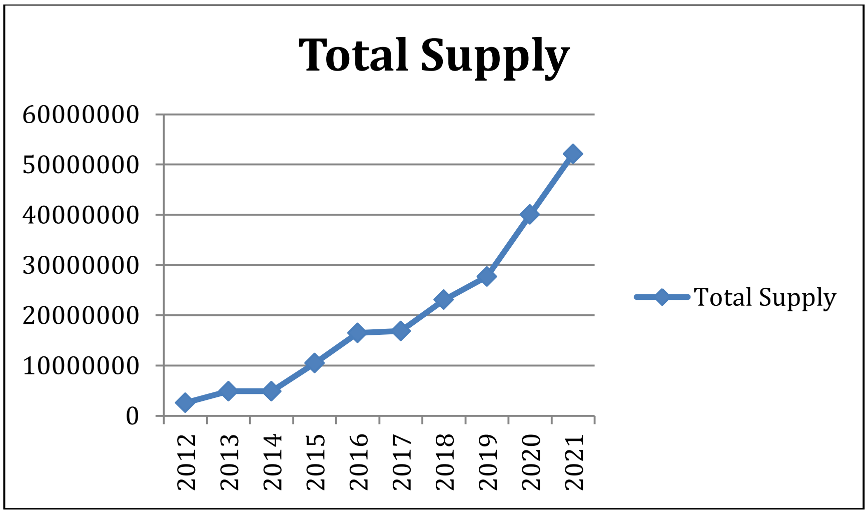


Figure 4: sugarcane supply during 2012-2021 Northeast Region

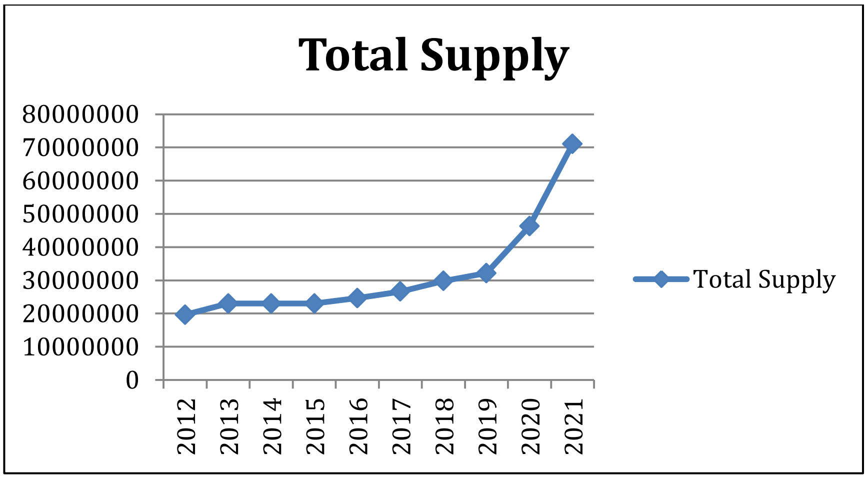


Figure 5: sugarcane supply during 2012-2021 East Region

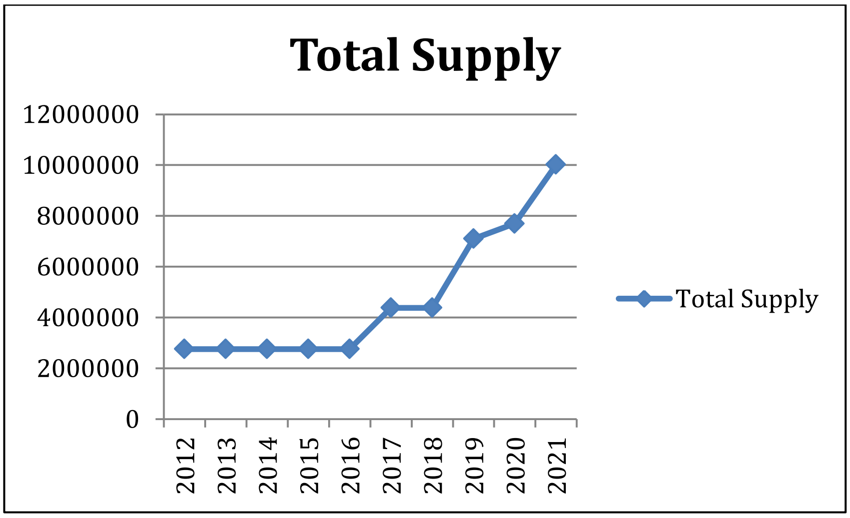


Figure 6-9 show the capacity of ethanol during year 2012-2021, additional capacity is needed since the beginning of the period to match with the ethanol production target of the New 10 Year Development Plan set by the government. The capacity keeps increasing every year. The total additional capacity needed of each plant in the 10 year period varies depending on factors of logistics and plant costs which shown in the figure.

Figure 6: Plant capacity during 2012-2021 North Region

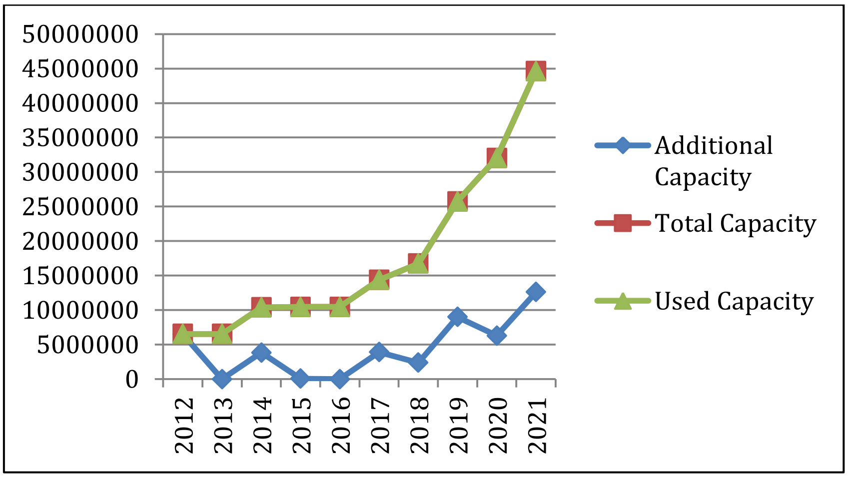


Figure 7: Plant capacity during 2012-2021 Central Region

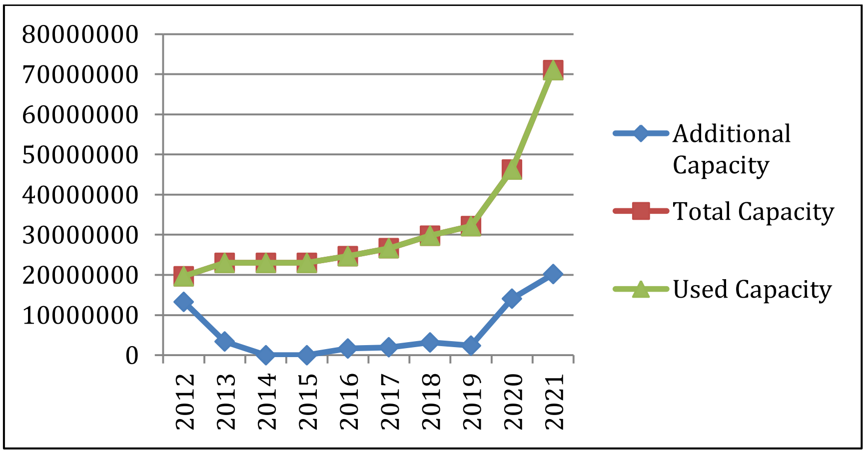


Figure 8: Plant capacity during 2012-2021 Northeast Region

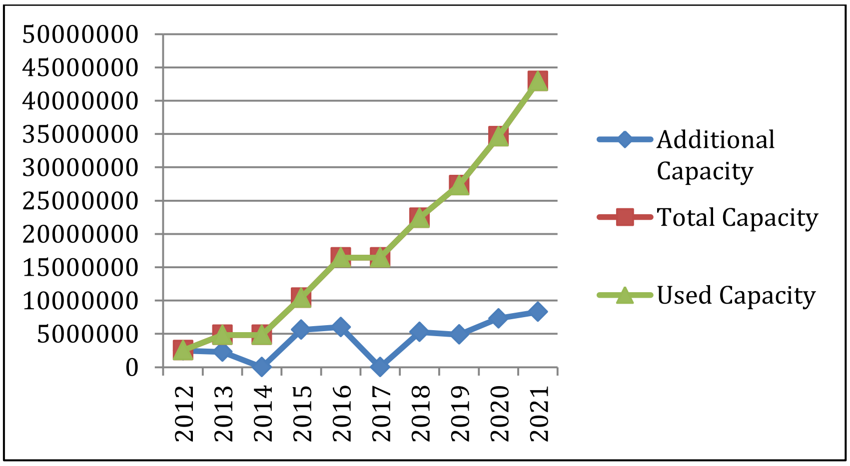
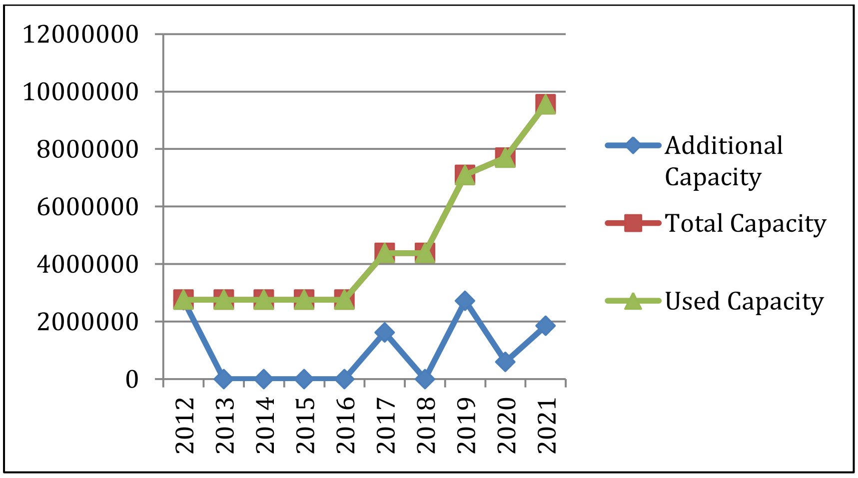


Figure 9: Plant capacity during 2012-2021 East Region



4.2 Logistics

Figure 10 shows logistics links of sugarcane production areas to ethanol processing plant area in ten years. There are 47 provinces as planting areas and 18 provinces as ethanol processing plant. From the figure, it showed the links of production of sugarcane in each province and serving plants (must sent to at least one ethanol plant). Some large size areas might need to send sugarcane to more than one ethanol plant because they yield large production. Furthermore, in order to minimize transportation cost, they try to send production of sugarcane to the nearest possible plant that has available capacity. However, there are some provinces that seem to send to far province. Since demand is increasing dramatically, in year 10, there is no available capacity near Phetchaburi and Prachuap Khirikhan. All the plants nearby reach their capacity limits. Therefore, sugarcane productions of the two provinces are sent to Phetchabun.

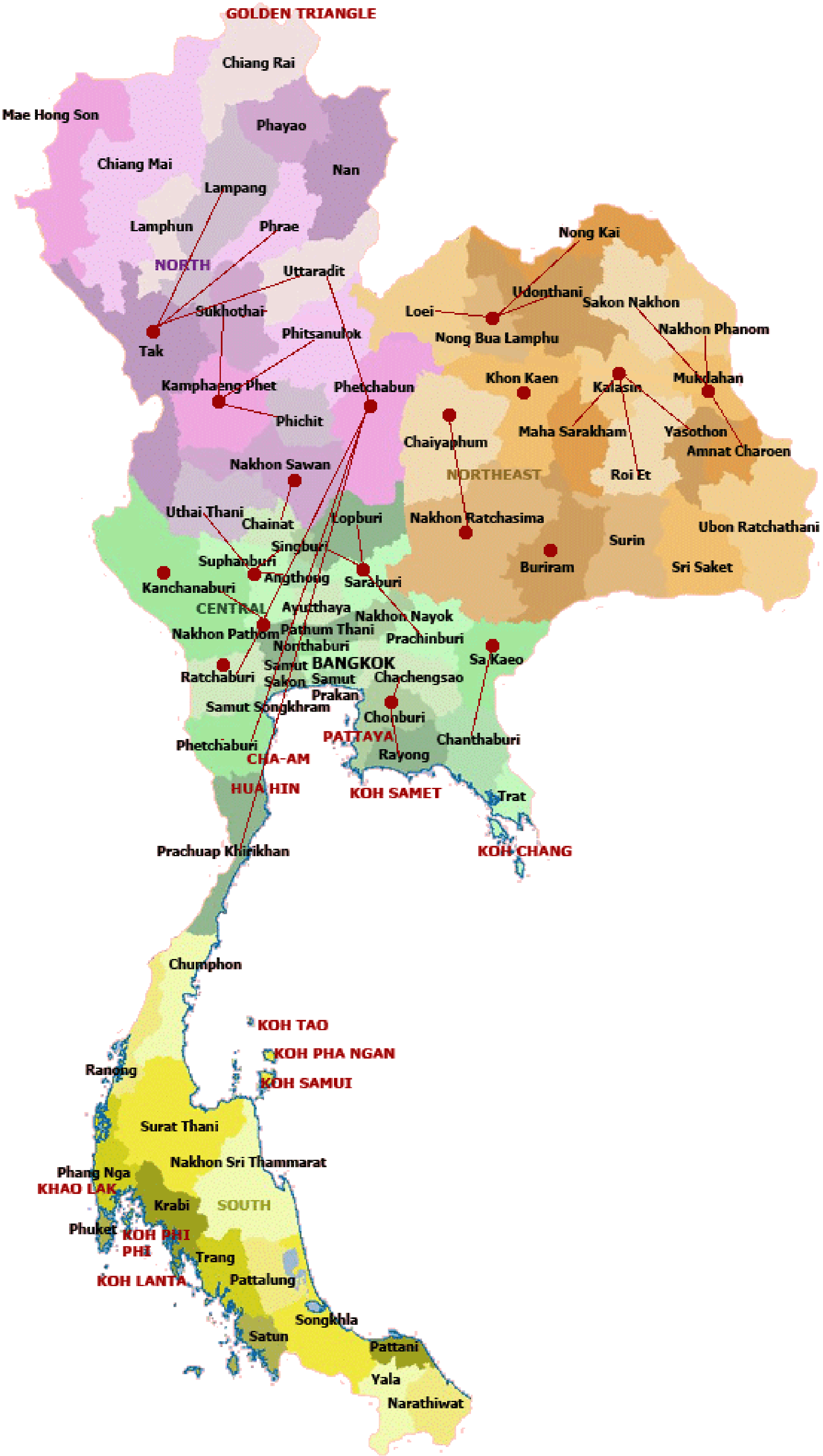


Figure 10: Map showing the matching of planting areas and the processing plants

5. CONCLUSION

In this research, we study a supply chain where the decision maker such as a company or government who wants to plan the production of sugarcane to meet the demand given the limited areas. The main objective of this research is to find a mathematical model to find the optimal decisions on crop production given limited space while minimizing the transportation distance from the planting area to the processing plants. The government can use the model to plan for the roadmap of crop production to follow the national agenda and the companies who are involved with agricultural planting can utilize the model and the insight to minimize cost from the limited land capacity and constraints from life cycle of crops. Our study promotes the usage of renewable energy with sufficient production planning. The mathematical model is proposed to make the production and logistics planning for sugarcane. The model takes into account the logistics cost, the facility cost, the limited area of planting and the limited capacity of processing plants. Moreover, the model also suggests the timeline to install additional capacities of processing plants and to use additional planting areas. The numerical experiment is conducted using a small-scale data set. We found the model works well to match the supply and demand by varying the starting and stopping time of sugarcane planting in each piece of land. However, to accurately determine the roadmap of Thailand, the more detailed data is needed. We found that the IBM ILOG CPLEX has difficulty solving large scale data sets. In the future research, the more accurate data of Thailand will be collected and the heuristic algorithm to solve the model efficiently will be proposed.

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