2012 2nd International Conference on Economics, Trade and Development
IPEDR vol.36 (2012) © (2012) IACSIT Press, Singapore

Mathematical Model of Production and Logistics Planning for Crops Producing E-20 Biofuel

Phongchayont Srisuwan and Aussadavut Dumrongsiri + +

Sirindhorn International Institute of Technology, Thammasat University 131 Moo 5 Tiwanont Road, Bangkadi,Muang, Pathumthani, 12000, Thailand

Abstract. Thailand uses cassava and sugarcane as the main crops to produce ethanol to mix with gasoline to produce E-20, a fuel mixture which contains 20% of ethanol and 80% of gasoline, as the crops are extensively planting in the country. At present, the fossil fuel price is continually rising and they are limited in supply, renewable fuels are an excellent alternative to prevent a dependency on this fuel. Moreover, the production of the combustion of ethanol does not emit pollutants to an environment. In this research, we study the production planning for crops used as ingredients of E-20, and optimal logistics solutions for distributing the crops to the plants in Thailand. 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, thereby reducing the emission of CO_2. The result of model will help provide the guideline to Thai government how to plan the crop production in the future..

Keywords: cassava, ethanol, logistics, production planning, renewable fuel, sugarcane, mathematical model.

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 a widely used as a source of energy throughout the world. It is consumed in huge quantity everyday in Thailand and also generating a great amount of greenhouse gases (GHG) which are likely to be 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 chemicals to the environment, and particulates of them can cause problems to human such as cancer, brain and nerve damage, and breathing problems. Conversely, oil is necessary for almost all machines to move and we live in an era where oil is necessary to produce, transport food, for movement of vehicles, airplanes etc. Unfortunately, we are facing a global energy crisis with natural reserves being depleted fast due to over consumption and now energy crisis is now a major concern in most part of the world. Meanwhile, the price of crude oil has been increased consecutively and the amounts of them are decreasing as well. Therefore, it is essential to seek for the substitute energy.

Thailand has a dependency on importing fuel from other countries which costs enormously each year. A renewable energy is an excellent alternative way to reduce foreign oil import and increase domestic renewable energy utilization. E-20 is a fuel mixture which blends 20 percent ethanol 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. E-20 was first launched in Thailand since January 2008 and was consumed approximately 29 million liters, and in 2010 was consumed approximately

+ Corresponding author. Tel.: +662-501-3505 ext. 2106; fax: +662-501-3505 ext. 2101.
E-mail address: aussadavut@siit.tu.ac.th.

137 million liters [1]. Thai government also supports and has launched a policy to promote the use of alternative energy for sustainable development in the national agenda [2]. An alternative energy can be utilized from domestic energy resources such as cassava and sugarcane, thus bringing economic benefits to concerned local communities.

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 or farmers who are involved with agricultural planting can utilize the model and the insight to maximize their profit from the limited land capacity and constraints from life cycle of crops. Our study promotes the usage of renewable energy with sufficient production planning, thereby reducing the emission of CO_2.

The rest of this paper is organized as below. First we provide a review on the literature related to our research. Second, we conduct the preliminary analysis and introduce the research model and the analysis of each factor. Finally, we draw a conclusion for our study and discuss implication for both research and practice.

2. Literature Review

In this section, we will provide an overview of the literature on bioethanol industry and bioethanol production. We will also review the relevant literature relating to transportation scheduling problem and location routing problem.

Thailand is heavily dependent on imported oil which accounts for more than 90% of all oils consumed annually. Thai government initiated the national ethanol fuel program in year 2000 to reduce the imported crude oil. One of the solutions is to use bio-ethanol derived from agro-products, then ethanol demand has grown rapidly [3]. Domestically produced ethanol has emerged as a potential substitute for conventional gasoline which is effective in fossil oil savings and pollution mitigation [4]. Previous literatures have studied the Life Cycle Analysis (LCA) concerning cassava and molasses-based bioethanol production and environmental impacts in Thailand which indicate that the gasohol consumes less fossil energy than conventional gasoline (CG) and reduces certain environmental loads compared to CG. Using biomass in place of fossil fuels for process energy in the manufacture of ethanol leads to improved overall life cycle energy and environmental performance of ethanol blends relative to CG [5], [6].

Next the transportation scheduling problem and location routing problem are discussed. In Thailand many of factories have faced one similar problem which is the imbalance of supply and demand due to uncertainties of agriculturists delivering lead-time and supply. Agriculturists often supply more than factory demands or factory capacity which causes queue and waiting in line [7]. However, the cost of transporting crops from the farm gate to the mills is quite high, owning to the multiple transport facilities and time-consuming activities involved in the delivery process. Transportation has become a significant factor affecting the production costs of commodities [8]. Furthermore, there was lack of coordination between harvesting, transporting and crushing schedules due to manual organization of these operations which could affect the quality of the crops as it is deteriorate very rapidly [9]. It is difficult for mill traffic officers to produce good transport schedules manually due to the need to service a large number of harvesters in different locations [10]. To fix this problem, the cost of production and logistics should be reduced especially transportation cost which is the largest unit cost [11].

Thailand is one of the world's major agricultural countries and is suitable for growing a wide variety of crops. Under Thailand's alternative energy plan, the government intends to promote the use of alternative fuels that can be made from raw materials that are abundant in Thailand such as cassava and sugarcane [12].

Cassava normally plants in two regions in Thailand which are east and northeast region. It is best to get the plant established before the major rains start to counter soil erosion, normally starts planting in March-May, or the beginning of rainy season, which gives the highest yields. Generally, cassava will be cultivated after planted for 12 months.

Sugarcane generally plants in four regions in Thailand which are north, central, eastern, and northeast region. Sugarcane cultivation could be starts at either the beginning or end of rainy season, April-June or October-January, respectively. Sugarcane will be cultivated after planted for 10-12 months. Once planted sugarcane, it can be harvested again without replanting, on the average, about three times in Thailand but it also relies on soil and water conditions as well. Usually, each successive harvest gives a smaller yield, and replanting is eventually needed.

3. Mathematical Model

3.1 Problem Description

This research considers the optimal productivity for planting main crops used as ingredients of E20, namely cassava and sugarcane, and optimal logistics solutions for distributing the crops to the plants in Thailand. These two crops are abundant and used as the major crops for ethanol production in Thailand. Currently, Thailand is the largest producer of sugarcane in South-East Asia and the world's third largest producer of cassava.

The objective is aimed at maximizing profit for the planner who is planting crops used as ingredients for ethanol production. In this research we focused on planting cassava and sugarcane. For cassava planting, we have variable cost as a cost of planting the crop. Cassava plantation once harvested, we have to replant again because the root is totally removed from the base of the plant. The profit from cassava production can be calculated from the revenue deduct the cost per period. As for sugarcane planting, we have variable cost and fixed cost which is a setup cost to start planting the crop. Once planted sugarcane, it can be harvested again without replanting because the crop still has the stump. The profit from sugarcane production can be calculated from the revenue deducted the total of variable and fixed costs. In conclusion, total profit from planting these two crops can be calculated from the sum of profits from planting these two crops deduct the transportation cost and fixed setup cost to start planting sugarcane.

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, thereby reducing the emission of CO2.

3.2 The Mixed Integer Linear Programming Model

To solve the described problem, the problem is formulated as Mixed Integer Linear Programming with the objective to maximize the profit and productivity from planting main crops used as ingredients of E-20 which are cassava and sugarcane and minimize the transportation cost for distributing the crops to the plants in Thailand. The model is coded with IBM ILOG CPLEX and numerical experiment is conducted to test the model.

The model is expressed as shown:

Index and Parameters:

$i = 1$ *means sugarcane and* $i = 2$ *means cassava*

$M = very\ large\ number > Max\ of\ c_{j,k,t}$

$N = number\ of\ rai\ per\ unit\ of\ land$

$K_1 = Set\ of\ plants\ processing\ sugarcane$

$K_2 = Set\ of\ plants\ processing\ cassava$

$K = K_1 \cup K_2$

$d_{j,k} =$ *transportation distance (in km) from land j to plant k*

$profit_{n,m} =$ *total costs per rai including both variable and fixed costs to plant sugarcane for* $m - n + 1$ *periods*

Decision variables:

$c_{j,k,t} =$ *amouts of crops (in tons) transported from land j to plant k in period t and 0 otherwise*

$y_{j,t+1} = 1$ *if* $x_{1,j,t}$ *changes from 0 in period t to 1 in period* $t+1$; *0 otherwise*

$z_{b,e,j} = 1$ *if* $\sum_{i=n}^{m} x_{1,j,t} = m - n + 1$ *(all x's are 1 between t = n and m); 0 otherwise*

($z_{b,e,j} = 1$ *is to indicate that the land j is assigned to plant sugarcane for all periods from n to m*)

$x_{i,j,t} = 1$ *if crop i is assigned to plant at land j in period t; 0 otherwise*

Mathematical Model:

$$Maximize\ Profit\ Z = N \times \sum_{t=1}^{T}\sum_{j=1}^{J}(p_c \times x_{2,j,t}) + N \times \sum_{j=1}^{J}\sum_{b=1}^{T}\sum_{e \ge b}^{T} profit_{b,e} \times z_{b,e,j} - N \times \sum_{t=1}^{T}\sum_{j=1}^{J}\sum_{k=1}^{K}(t \times d_{j,k} \times c_{j,k,t}) - N \times \sum_{j=1}^{J}\sum_{t=2}^{T} y_{j,t} \times f_s \qquad (3.2.1)$$

Subject to:

$$\sum_{t=1}^{I} x_{i,j,t} \le 1\ for\ all\ j,\ and\ t \qquad (3.2.2)$$

$$\sum_{j=1}^{J} N \times (ethanol\ from\ sugarcane\ per\ rai \times x_{1,j,t}) + additional\ ethanol\ in\ first\ year\ per\ rai \times y_{j,t}) + \sum_{j=1}^{J} N \times (ethanol\ from\ cassava\ rate\ per\ rai \times x_{2,j,t}) \ge ethanol\ demand_t\ for\ all\ t \qquad (3.2.3)$$

$$(1 - x_{1,j,t})M \ge c_{j,k,t}\ for\ all\ k \in K_2,\ for\ all\ j\ and\ t \qquad (3.2.4)$$

$$(1 - x_{2,j,t})M \ge c_{j,k,t}\ for\ all\ k \in K_1,\ for\ all\ j\ and\ t \qquad (3.2.5)$$

$$\sum_{k \in K} c_{j,k,t} \le (x_{1,j,t} \times sugarcane\ output\ per\ rai\ (in\ tons) \times N + x_{2,j,t} \times cassava\ output\ per\ rai\ (in\ tons) \times N)\ for\ all\ j,t \qquad (3.2.6)$$

$$\sum_{j} c_{j,k,t} \le Plant\ capacity_k\ for\ all\ k \in K\ and\ all\ t \qquad (3.2.7)$$

$$\sum_{l=b}^{e} x_{1,j,l} \ge (b - e + 1) \times z_{b,e,j}\ for\ all\ b \in \{1,...,T\}, e \in \{b,...,T\}, j \in \{1,...,J)\qquad (3.2.8)$$

$$M(1-z_{b,e,j}) \geq \sum_{m=b}^{e-1}\sum_{n=m}^{e} z_{m,n} \; for \; all \; b \in \{1,...,T\}, e \in \{b,...,T\}, j \in \{1,...,T\} \quad (3.2.9)$$

$$x_{i,j,t}, y_{j,t} \in \{0,1\}, c_{j,k,t} \geq 0 \quad (3.2.10)$$

$$x_{1,j,t+1} - x_{1,j,t} \leq y_{j,t+1} \; for \; all \; t = 1...T \; and \; all \; j \quad (3.2.11)$$

From the objective function (3.2.1) is to maximize the profit from planting main crops used as ingredients of E20 which are cassava and sugarcane. We defined that each land piece can be planted only one crop, either cassava or sugarcane (3.2.2). (3.2.3) sets up the productivity of the crops must be exceeded the ethanol demand. (3.2.4) and (3.2.5) state that if the land piece is assigned for one crop, the crop is not allowed to send to the other crop's plant, for instance, if the land piece is assigned for sugarcane, it cannot send to cassava plant and vice versa. (3.2.6) specifies that the sum of crops that will be sent to all plants cannot exceed the production of the land unit. (3.2.7) illustrates the total crops that received by a plant cannot exceed the capacity of each plant. (3.2.8) finds the sugarcane planting periods consecutively. (3.2.9) and (3.2.10) put constraints, for sugarcane planting, for all z for subset inside *b* and *e* to be zero when $z_{b,e,j}$ equals 1 which means the land piece is assigned to plant sugarcane for all periods from *n* to *m*. Lastly, (3.2.11) verifies the startup of sugarcane planting when it should be replanted.

4. Conclusion

In conclusion, this research is aimed to investigate the optimal productivity for planting main crops, cassava and sugarcane, used as ingredients of E-20, and the optimal logistics solutions for distributing the crops to the plants in Thailand. The model is equivalent to multi-machine, multi-product production planning with variable and fixed costs. Each unit of land is considered as one machine. The model will result in the optimal schedule of production for each unit of land over time. In addition, the prices and production rates can vary over time. The model is coded with IBM ILOG CPLEX and numerical experiment is conducted to test the model. Finally, the time-partitioning model will be developed in future work.

5. References

[1] Suksri, P. (2011). *Demand for gasohol and pricing policy in Thailand*. Thammasat Economic Journal , 29 (3).

[2] Bloyd, C. (2009). *An update on ethanol production and utilization in Thailand.* U.S.: Pacific Northwest National Laboratory.

[3] Chumnong Sorapipatana, Suthamma Yoosin. *Life cycle cost of ethanol production from cassava in Thailand,* Renewable and Sustainable Energy Reviews 15 (2011) 1343-1349.

[4] Thu Lan T. Nguyen, Shabbir H. Gheewala and Savitri Garivait (2006). *Life cycle cost analysis of fuel ethanol produced from cassava in Thailand*. The 2nd Joint International Conference on Sustainable Energy and Environment (SEE 2006).

[5] Thu Lan T, Nguyen, Shabbir H, Gheewala (2008). *Life cycle assessment of fuel ethanol from cane molasses in Thailand.* International Journal Life Cycle Assess (2008) 13: 301-311.

[6] Thu Lan T. Nguyen and Shabbir H. Gheewala (2007). *Life cycle assessment of fuel ethanol from cassava in Thailand*, Wood and other renewable resources.

[7] Jirawan Yosnual, Srisawat Supsomboon, *A stochastic model for optimal order quantity for sugarcane factory with uncertainties*, Proceedings of the Fifth Asia Pacific Industrial Engineering and Management Systems Conference 2004.

[8] Paitoon Chetthamrongchai, Aroon Auansakul, Decha Supawan (2001). *Assessing the Transportation Problems of the Sugar Cane Industry in Thailand***.** Transport and Communications Bulletin for Asia and the Pacific No.70, 2001.

[9] Andrew Higgins, George Antony, Gary Sandell, Ian Davies, Di Prestwidge, Bill Andrew, *A framework for integrating a complex harvesting and transport system for sugar production*, Agricultural Systems, Volume 82, Issue 2, November 2004, Pages 99-115, ISSN 0308-521X, 10.1016/j.agsy.2003.12.004.

[10] Andrew Higgins, *Scheduling of road vehicles in sugarcane transport: A case study at an Australian sugar mill*, European Journal of Operational Research, Volume 170, Issue 3, 1 May 2006, Pages 987-1000, ISSN 0377-2217, 10.1016/j.ejor.2004.07.055.
[11] N. Chiadamrong, R. Kawtummachai, *A methodology to support decision-making on sugar distribution for export channel: A case study of Thai sugar industry*, Computers and Electronics in Agriculture, Volume 64, Issue 2, December 2008, Pages 248-261, ISSN 0168-1699, 10.1016/j.compag.2008.05.018.
[12] Kulwarang Suwanasri, *Raw materials for biofuel/biomass production in Thailand.* Policy study and biosafety division, BIOTEC. Retrived January 2012 from http://www.biotechthailand.com/IndProf/TH-BIO/2009/TH-BIO_0809_IP15.pdf