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A Linear Programming Approach to Optimize Natural Rubber Production

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Abstract
*This article describes the design of a linear programming model to optimize production of natural rubber in Malaysia. Uptrend in natural rubber production which occurred after 2015 did not last long. Area for rubber cultivation was not only affected by efforts to convert rubber estates into real estate developments but also by factors such as increase in farmers' interest to cultivate oil palm, unstable rubber price, lengthy duration of low rubber price, insufficient number of rubber tappers, long waiting time before tapping rubber trees, changing land conditions for crops, and buyout offers for rubber wood from furniture-manufacturing factories. Results from two different software, namely Excel Solver and QM for Windows were compared. No significant difference in value was observed to take place***, *thus the development of linear programming model was considered to be successful.*

Keywords: *attractive corners, constraint, feasible region, linear programming, optimization*

Introduction

Malaysia is ranked fifth as a world producer of rubber. When the new economic policies were introduced in 1971, the industry generated RM1.74 billion in the export values. In the year 2013, the values of export had increased to RM33.7 billion. Natural rubber (NR) will continue to function as a strategic crop due to the interest of industry to manufacture rubber-based products. The use of rubber material is expected to continue growing rapidly within the country and also globally based on projection of Malaysia's economic structure by TN50 (Malaysian Rubber Board, 2011). Rubber product industry in Malaysia includes latex product, tyre, tyre-related products and shoes. As a result of an increase in domestic downstream rubber, domestic consumption of rubber has increased from 419,000 tons in 2000 to 434,000 tons in 2013, 87% of which are latex products. The first sets of outputs of latex products included gloves, condom, catheters and rubber thread (Eng, 2001).

Uptrend in rubber production began in 2015. Production of natural rubber increased by 36.8%, namely from 14,367 tons (May 2015) to 53,383 tons (June 2015). This volume increased further by 41.4% to 124.6 kilogram per hectare. However, only approximately 1.45 % change was observed in the volume change at the end of 2014 to early 2015 (Department of Statistics Malaysia, 2016). Interestingly, the average monthly price for latex was observed to have increased by 10.9% to 496.52 cent per kilogram in June 2015 (Natural Rubber Statistics, 2016). This increasing trend did not last. Natural rubber production dropped by 4% to 45,279 tons from June 2016 to July 2016 (Department of Statistics Malaysia, 2016). The drop in natural rubber production was affected by the loss of rubber estates which were transformed into real estate developments or oil palm plantations.

The area for rubber cultivation was also seen shrinking due to factors such as more farmers' interest to cultivate oil palm, rubber prices were unstable and have been in the low for a long period, insufficient number of rubber tappers, long waiting time before tapping rubber trees, changing land conditions for crops, and buyout offers for rubber wood from furniture-manufacturing factories (Federal Land Development Authority, 2014). Hence, the constraints affecting planting areas of natural rubber should be maximized in order to optimize the natural rubber production.

Use of Models for Optimizing Crop Production

The discussion in this section is divided according to two themes: i) use of models for optimizing crop production and ii) use of POM-QM for Windows.

i. Use of Models for Optimizing Crop Production

Table 1 displays several research works at optimizing production of crops such as natural rubber, sugar cane, and watermelon included the use of goal programming, Artificial Neural Network (ANN), linear programming and forecasting.

Table 1: Previous works at optimization of crop production

Author (year)	Findings
Hassan et al. (2013)	Goal programming approach method was used to maximize rubber production and planted areas of rubber. Goal programming deals with the multiple objectives decision-making problems. In this research, two objectives were developed to optimize the rubber planted areas and its production. A decision variable that was considered was the rubber planted area in hectares. The findings indicated that rubber production can be increased by increasing the planting area.
Obe and Shangodoyin(2010)	ANN model was developed in this study to forecast sugar cane production in Nigeria. The performance of the ANN model was measured using the Mean Squared Error (MSE), Normalized Mean Squared Error (NMSE), correlation coefficient (r), Akaike's Information Criterion (AIC) and Minimum Description Length (MDL). Results obtained showed that 85.70 % accuracy was obtained by ANN at predicting sugar cane production output.
Urrutia et al. (2002)	The research was conducted in Candaba, Pampanga. Linear programming model was developed to maximize the profit of small-scale farmers in the production of watermelon and melon. Constraints considered were budgets for seeds, plant operating expenses, delivery requirements or demands in the market and the area of planting field. Results showed maximum revenue of PHP 701,340 was obtained by planting 7,284 seeds of watermelon and 2,584 seeds of melon.

The suitable method for this case study is linear programming because there are similarities with previous works and it focuses only on a single linear objective function.

ii. Use of POM-QM for Windows

Linear programming calculations in this case study have used Excel Solver. QM for Windows has been chosen here to validate the answers obtained. According to Weiss (2011), POM-QM for Windows provides mathematical analysis for Operations Management, Quantitative methods, or Management Science. It also features calculation methods for PERT/CPM, Linear Programming, Decision Analysis, Transportation problem, Statistical functions, Game Theory, Goal Programming, etc. Excel Solver uses a series of rules and computations to optimize a solution and the rules can be adjusted by the user. On the contrary, QM is designed specifically for equations. It will return optimum values for correctly defined equations.

Methodology

According to Fah (2011), data analysis is the process of compiling the data collected and the data is then divided into units that are simpler to facilitate in interpretation. In this study, data collected is categorized according to Malaysia's natural rubber consumption and production of natural rubber per area. The data is stored and solved using Excel solver and Quantitative

Method (QM) software. A 10-year time series data from 2006 to 2015 was obtained from Malaysian Rubber Board. The objective function of the linear programming used to maximize the production of natural rubber is given below:

$$\text{Maximize: } Z = \sum_{i=1}^{n} c_i X_i = c_1 X_1 + c_2 X_2 \tag{1.0}$$

where:

X_1 = Malaysia's natural rubber consumption
X_2 = production of natural rubber per area
c_1 = the profit of using X_1
c_2 = the profit of using X_2

subject to:

$$a_{j,i} X_1 \leq b_j \tag{1.1}$$

$$a_{j,i} X_2 \leq b_j \tag{1.2}$$

$$X_1, X_2 \geq 0 \quad \text{(Non-negativity conditions)} \tag{1.3}$$

where:

$a_{j,i}$ = the amount of resource *j* used for each unit of activity
b_j = total amount of resource *j*

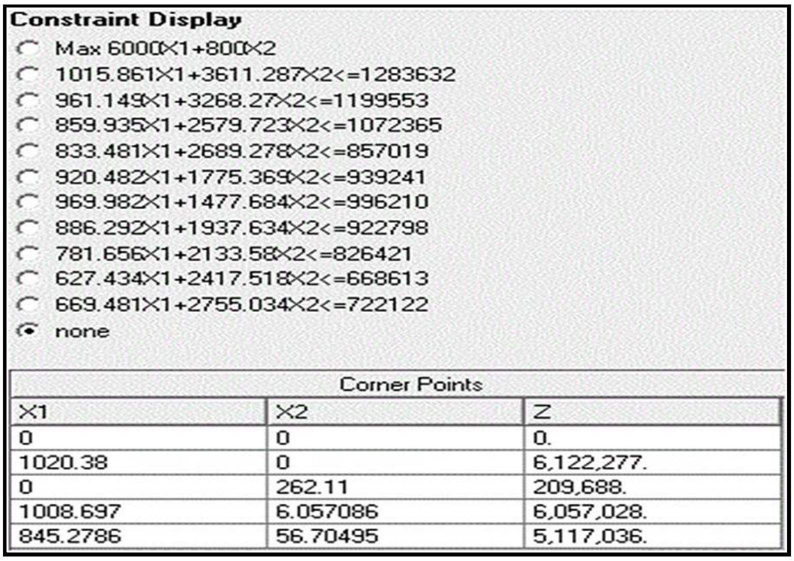
Results and Discussion

Table 2 presents optimum production results from Excel Spreadsheets. In particular, the optimal production of natural rubber per area was found to be 6,122,290,544.25 tons.

Table 2: Optimization in Excel

	A	B	C	D	E	F	G
1							
2		Consumption (Tons)	Production per area (Tons/Hectare)	Left Hand Side		Right Hand Side	Slack
3	Objective function	8770	6000	6122290544.25			
4	2006	383,324	1.01586	1036565.01	<=	1,283,632	247,066.99
5	2007	450,246	0.96115	980739.93	<=	1,199,553	218,813.07
6	2008	468,894	0.85994	877467.09	<=	1,072,365	194,897.91
7	2009	468,669	0.83348	850467.79	<=	857,019	6,551.21
8	2010	457,919	0.92048	939241.00	<=	939,241	0.00
9	2011	401,923	0.96998	989749.90	<=	996,210	6,460.10
10	2012	441,398	0.88629	904354.15	<=	922,798	18,443.85
11	2013	434,192	0.78166	797591.60	<=	826,421	28,829.40
12	2014	448,484	0.62743	640218.13	<=	668,613	28,394.87
13	2015	474,773	0.66948	683125.18	<=	722,122	38,996.82
14							
15	Solution Values	0	1020382				

This type of problem can also be solved graphically in the QM software since there are only two variables involved. A graph was drawn with the x-axis and the y-axis representing Malaysia's natural rubber consumption and production of natural rubber per area, respectively. The two constraint lines were plotted by finding the x and y-intercepts for both constraint equations. In particular, Figure 1 displays the constraints specified for this case study as displayed in QM for Windows**.**



Constraint Display

- Max 6000X1+800X2
- 1015.861X1+3611.287X2<=1283632
- 961.149X1+3268.27X2<=1199553
- 859.935X1+2579.723X2<=1072365
- 833.481X1+2689.278X2<=857019
- 920.482X1+1775.369X2<=939241
- 969.982X1+1477.684X2<=996210
- 886.292X1+1937.634X2<=922798
- 781.656X1+2133.58X2<=826421
- 627.434X1+2417.518X2<=668613
- 669.481X1+2755.034X2<=722122
- none

Corner Points

X1	X2	Z
0	0	0.
1020.38	0	6,122,277.
0	262.11	209,688.
1008.697	6.057086	6,057,028.
845.2786	56.70495	5,117,036.

Figure 1: Constraint Display

The two constraint lines were plotted by finding the x and y-intercepts for both constraint equations. Area on the valid side for all constraint lines is called the feasible region. Since the objective of the study aimed to optimize the natural rubber production to maximize the profit, Z, a line parallel to the objective function lines was drawn and it touched the last point in the feasible solution, as shown in Figure 2. By definition, the most attractive corner is the last point in the feasible solution region touched by a line that is parallel to the objective function lines (Reeb and Leavengood, 1998). This point when identified will give the amounts of natural rubber production that can maximize profit.

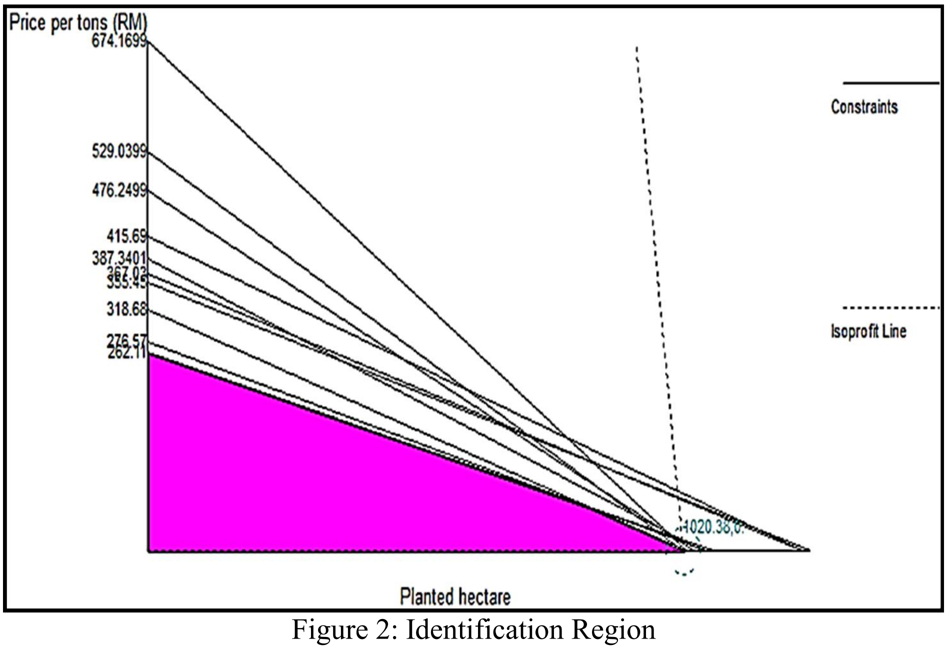


Figure 2: Identification Region

Figure 3 shows the optimum result obtained from production optimization by using QM for Windows. As can be seen, optimal production of natural rubber per area has been given by points$X_1 = 0$ and $X_2 = 1020382$,similar to that found using Excel Solver.

Variable	Status	Value
X1	NONBasic	0
X2	Basic	1020382.0
slack 1	Basic	247067.0
slack 2	Basic	218813.1
slack 3	Basic	194897.9
slack 4	Basic	6551.212
slack 5	NONBasic	0
slack 6	Basic	6460.097
slack 7	Basic	18443.84
slack 8	Basic	28829.37
slack 9	Basic	28394.85
slack 10	Basic	38996.79
Optimal Value (Z)		6122291000

Figure 3: Optimal Solution in QM for Windows

Reliable results must be able to replicate the real life system, in this case the natural rubber production (Murugan et al., 2013). As stated earlier on, results in Excel may be subject to errors but QM for Windows will return optimum values for correctly defined equations. A summary of results obtained from using Excel and QM for Windows is given in Table 3. The profits which were closely similar in value (6,122,290,000 tons) were generated by attractive corners assigned to$X_1 = 0$ and$X_2 = 1020382$.

Table 3: Results from Excel and QM for Windows

Variables	**Solution by using POM-QM for Windows**	**Solution by using Excel**
X_1	0	0
X_2	1,020,382	1,020,382
Profit	6,122,291,000	6,122,290,544

Conclusion

The result of the proposed model is similar to that generated by QM for Windows software. Thus, this case study has successfully developed a linear programming model which can optimize natural rubber production in Malaysia. Many other constraints may affect production of natural rubber such as conditions of the rubber trees, numbers of workers, climate, import and export of natural rubber, and development of industrial technologies. It is recommended that these factors be taken into consideration in future works in this area.

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