OPTIMIZING FERTILIZER COMPOUNDS FOR PINEAPPLE PRODUCTION USING THE GOAL PROGRAMMING APPROACH

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Abstract

Pineapple, a fruit under the Bromeliaceae family, is one of the most popular tropical fruits in Malaysia. Similar to other fruits, it requires fertilizer to grow efficiently. Fertilizer is any material of synthetic origin that is applied to soils. The function of fertilizer in growing plants is to increase tissues supply and increase necessary nutrients to the plants. The aim of this research is to reduce the overall fertilizer expense in pineapple plantation and reduce nitrogen-phosphorus-potassium (NPK) fertilizer's utilization (upper and lower limits) via the Goal Programming (GP) algorithm. The study focuses only on cultivation of one type of crop which is pineapples. Five fertilizers with different contents of NPK were analyzed. The result showed that 107.73 kg/ha of NPK 16/16/16, 102.92 kg/ha of Special Red, 85.47 kg/ha of NPK 44, 101.07 kg/ha of NPK Green and 90.58 kg/ha of NPK Blue are necessary to optimize pineapple production. This combination can help farmers to use the right amount of NPK fertilizers in pineapple production and reduce overall cost of production.

Keyword: Goal Programming Approach, NPK Fertilizers, Pineapple Production

Introduction

Goal Programming (GP) is one of the most popular multi-criteria decision-making algorithms. Introduced by Sen & Nandi (2012), this technique that is categorized under multi-objective linear programming is important in tackling large-scale decision-making problems.

Pineapple is one the most popular tropical fruits in Malaysia. It is the only major crop in the Bromeliaceae family. Pineapples are planted in all over Malaysia, but the crop is mainly scattered in Johor, Sarawak and Sabah (Nurul & Fazleen, 2019). Two pineapple varieties, N36 and Josapines, are the main breeds highly demanded for export purposes various countries including United Arab Emirates (UAE) and Singapore due to their durability and extended storage life (Ali et al., 2010).

Nitrogen-phosphorus-potassium (NPK) is an organic fertilizer that consists of three different compounds which are nitrogen, phosphorus and potassium. The purpose of using fertilizer in growing plants is to increase the plants' tissue supply and provide necessary nutrients. A balanced NPK formulated fertilizer is usually referred to as chemical fertilizer, and NPK fertilizer is used to provide additional nitrogen, phosphorus and potassium required by crops. Nowadays, because fruits are grown all year round, sweetness and quality of the fruit will vary depending on the different nutrients used.

There are many types of NPK fertilizers used for pineapple plantations but the chosen NPK fertilizers for this research are NPK 16/16/16, NPK Special Red, NPK 44, NPK Green and NPK Blue. NPK ratio contained in NPK 16/16/16 is 16:16:16, NPK Special Red is 13:13:21, NPK 44 is 12:6:22, NPK Green is 15:15:15 and NPK Blue is 12:12:17. The five NPK blends stated above are carefully formulated with specific nutrients compound and encased with two layers of wax which prevents leaf burn and makes them to not stick to the pineapple leaves. Pineapples

need to be properly fertilized since overutilization of fertilizers will result to serious damage to environment while underutilization of fertilizers will result to subpar crop quality. Rahman and Zhang (2018) found that overuse of NPK fertilizers will result to increased amount of nitrate remaining in the soil. Making things worse, due to leaching, this issue will cause groundwater and atmospheric pollution. Overutilization or underutilization of fertilizer compounds in pineapple plantation will lead to low productivity, thus, it is important to obtain the right combination of nitrogen, phosphorus, and potassium in fertilizers to produce high quality and high yield of pineapple.

Materials and Methods

Research Goal

The aim of this study is to build a GP algorithm to optimize pineapple yield, minimize overall fertilizers expense, and minimize lower and upper limits of compounds in NPK fertilizers for pineapple plantation. LINGO 18.0 software was used to achieve these objectives.

Data Collection

This study is conducted on five NPK fertilizers used for pineapple production at Lembaga Perindustrian Nanas Negeri Sembilan, Malaysia. There are 5 decision variables in the fertilizer content to be considered where x_i is the mass in kg of fertilizer i per hectare.

Table 1 Types of Fertilizer Used in Pineapple Production

i	Fertilizer	N (%)	P (%)	K (%)	Price (RM/kg)
1	NPK 16/16/16	16	16	16	1.60
2	NPK Special Red	13	13	21	1.55
3	NPK 44	12	6	22	1.40
4	NPK Green	15	15	15	1.45
5	NPK Blue	12	12	17	1.35

There are upper and lower limits for each compound in NPK fertilizers as shown in **Table 2**.

Table 2 Lower and Upper Limits Compound of NPK Fertilizer

Compound of fertilizer	Lower limit (kg/ha)	Upper limit (kg/ha)
N	80	140
P	75	125
K	60	120

For one hectare of land, total number of pineapples that can be planted is 15 000, and each plant will require 0.02 kg of fertilizers. Thus, the total cost of fertilizers used for pineapple production for one hectare of land is calculated as below:

Table 3 Calculation for Total Cost of Fertilizers

Fertilizer	Calculation for Cost of Fertilizers	Cost (RM/ha)
NPK 16/16/16	RM 1.60 × 0.02 kg × 15 000	480
NPK Special Red	RM 1.55 × 0.02 kg × 15 000	465
NPK 44	RM 1.40 × 0.02 kg × 15 000	420
NPK Green	RM 1.45 × 0.02 kg × 15 000	435
NPK Blue	RM 1.35 × 0.02 kg × 15 000	405
Total Cost of Fertilizers		2205

Goal Programming Method

To obtain the aim of this study, Pre-Emptive Goal Programming Model is utilized. The general Pre-Emptive Goal Programming Model is as follows (Kumar, 2019):

Minimize $Z = \sum_{i=1}^{m} p_i \left(d_i^+ + d_i^- \right);\ i = 1, 2, 3, \ldots, m$

Subject to:

$$\sum_{j=1}^{n} c_{i,j} y_j - d_i^+ + d_i^- = A_i;\ j = 1, 2, \ldots, n$$

$$\sum_{j=1}^{n} c_{i,j} y_j \left| \begin{matrix} \geq \\ = \\ \leq \end{matrix} \right| A_i;\ i = m+1, \ldots, m+p$$

$$y_j, d_i^+, d_i^- \geq 0$$

In terms of priority, types of variables to be minimized for this research are as follows: first d_1^+, second $d_2^- + d_3^- + d_4^-$ and third $d_5^+ + d_6^+ + d_7^+$. The most important objective is to minimize the overall fertilizer expense, while the side objectives are to minimize the amount of lower limit of nutrients (underutilization) and to minimize the amount of upper limit of nutrients (overutilization). These priorities can be structured as:

P1: Minimize the total cost in fertilizer combination; Minimize d_1^+

P2: Minimize underutilization of the lower limit of nutrients; Minimize $d_2^- + d_3^- + d_4^-$

P3: Minimize overutilization of the upper limit of nutrients; Minimize $d_5^+ + d_6^+ + d_7^+$

Minimize $Z = P_1(d_1^+) + P_2(d_2^- + d_3^- + d_4^-) + P_3(d_5^+ + d_6^+ + d_7^+)$ (1)

Construction of GP model:

Cost of fertilizers

$$1.60x_1 + 1.55x_2 + 1.40x_3 + 1.45x_4 + 1.35x_5 + d_1^- + d_1^+ \leq 2205 \quad (2)$$

Lower limits of NPK

$$0.16x_1 + 0.13x_2 + 0.12x_3 + 0.15x_4 + 0.12x_5 + d_2^- - d_2^+ \geq 80 \quad (3)$$

$$0.16x_1 + 0.13x_2 + 0.06x_3 + 0.15x_4 + 0.12x_5 + d_3^- - d_3^+ \geq 75 \quad (4)$$

$$0.16x_1 + 0.21x_2 + 0.22x_3 + 0.15x_4 + 0.17x_5 + d_4^- - d_4^+ \geq 60 \quad (5)$$

Upper limits of NPK

$$0.16x_1 + 0.13x_2 + 0.12x_3 + 0.15x_4 + 0.12x_5 + d_5^- - d_5^+ \leq 140 \quad (6)$$

$$0.16x_1 + 0.13x_2 + 0.06x_3 + 0.15x_4 + 0.12x_5 + d_6^- - d_6^+ \leq 125 \quad (7)$$

$$0.16x_1 + 0.21x_2 + 0.22x_3 + 0.15x_4 + 0.17x_5 + d_7^- - d_7^+ \leq 120 \quad (8)$$

Results and Discussion

Results of the Pre-Emptive Goal Programming algorithm on finding the optimum mix of NPK fertilizer for pineapple plantation in previous section is discussed in this section. The solution to $x_1 = 107.73$, $x_2 = 102.92$, $x_3 = 85.47$, $x_4 = 101.07$ and $x_5 = 90.58$. This implies that 107.73 kg/ha of NPK 16/16/16, 102.92 kg/ha of NPK Special Red, 85.47 kg/ha of NPK 44, 101.07 kg/ha of NPK Green and 90.58 kg/ha of NPK Blue are the optimum amount of fertilizer mix for one hectare of pineapple production. The most important objective is to minimize overachievement of overall expense on fertilizer mix was achieved where d_1^+ equals to zero. The second most important objective to minimize underutilization of lower limit of nutrients was not obtained where d_2^-, d_3^- and d_4^- are 193.63, 191.68 and 104.17. Meanwhile, for the last objective to minimize overutilization of upper limit of nutrients was accomplished where the positive variables for d_5^+, d_6^+ and d_7^+ equals to zero. Last but not least, the total cost is reduced by RM 1 484.61 which is from RM 2 205 to RM 720.39.

Conclusion

This study attempts to deal with the nutrient management problem of pineapple plantation using the GP model. The study found that the total fertilizer cost required for one hectare of plantation can be significantly minimized, thus achieving one of the objectives of this study which is to minimize the overall expense of pineapple plantation. However, the other objective of optimizing fertilizer compounds was not achieved because the second-priority goal which

is to minimize underutilization of the lower limit of nutrients was not achieved. The results can be improved via experts' help to analyze the amount of each NPK fertilizer and its specific functions. This move can help farmers to use the perfect amount of NPK fertilizer in pineapple production. This goal programming approach is also useful for agricultural planners to guide farmers in reducing the overall cost of production.

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Conflict of Interests

The researchers hereby declare that there is no conflict of interest with any organization or financial body in conducting this study.

References

Ali, A. K., Abidin, A. Z. Z., Suntharalingam, C. a. p., Zainal, M. A., Zakaria, M. H., Halim, N.A., . . . Hamir, N. A. (2010). Potensi dan Strategi Pemasaran Buah-buahan Tempatan, 60-70.

Anggraeni, W., Permatasari, J., Tyasnurita, R., & Vinarti, R. A. (2015). Production Planning Optimization Using Goal Programming Method in Habibah Busana. *Journal of Advanced Management Science*, 270-275. doi:10.12720/joams.3.4.270-275

Domingo, J., Mínguez, M. I., & Romero, C. (1988). Determining Optimum Fertilizer Combinations Through Goal Programming with Penalty Functions: An Application to Sugar Beet production in Spain. *Journal of the Operational Research Society, 39*(1), 61-70. doi:10.1057/jors.1988.8

Fatah, F. A., & Suhaimi, N. H. M. (November 2019). Profitability of Pineapple Production (Ananas comosus) among Smallholders in Malaysia. *International Journal of Recent Technology and Engineering (IJRTE), 8*(4).

Ghosh, D., Mattison, D. M., & Sharma, D. K. (2005). Goal programming formulation in nutrient management for rice production in West Bengal. *International Journal of Production Economics, 95*(1), 1-7. doi:https://doi.org/10.1016/j.ijpe.2003.09.018

Hassan, K. B., Hassan, N., Yusof, S. A., & Yatim, S. S. (2013). Optimizing Fertilizer Compounds and Minimizing the Cost of Cucumber Production using the Goal Programming Approach. *American-Eurasian Journal of Sustainable Agriculture, 7*(2), 45-49.

Hassan, N., Raduan, N. H. M., Safiai, S., & Ayop, Z. (2012). Goal Programming Formulation in Nutrient Management for Chilli Plantation in Sungai Buloh, Malaysia. *Advances in Environmental Biology, 6*(12), 4008-4012.

Kumar, P. P. (October 2019). Goal Programming Through Bakery Production. *International Journal of Scienctific & Technology Research, 8*(10).

Pazil, A. H. M., Hassan, N., Idris, N. S., & Razman, N. F. (2013). A Goal Programming Model for Bakery Production. *Advances in Environmental Biology, 7*(1), 187-190.

Rahman, K., & Zhang, D. (2018). *Effects of Fertilizer Broadcasting on the Excessive Use of Inorganic Fertilizers and Environmental Sustainability* (Vol. 10).

Sen, N., & Nandi, M. (2012). A Goal Programming Approach to Rubber Plantation Planning in Tripura. *Applied Mathematical Sciences, 6*(124), 6171-6179.

Sen, N., & Nandi, M. (2012, September). Goal Programming, its Application in Management Sectors- Special Attention into Plantation Management: A Review *International Journal of Scientific and Research Publications, 2*(9).