Heuristics in Land use Optimization and Determination of Agricultural Product Warehouse

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ABSTRACT

This research aims to offer a solution to manage long-term crop planning to control the production quantity and maximize profit. The problems were that many crops could grow together in the cultivated area depending on the type of crops, the time of cultivation, and cultivated some crops in multiple periods within that year. The linear programming model gave an optimal solution and compared it with the Fractional Knapsack Problem Algorithm. The objective were to manage long-term crop planning to control the quantity of production and maximize profit, comprised of the cost of cultivation on cultivated area, cost of opportunity that crop yield less than the demand, cost of changing crop type on cultivated area, cost of transportation from cultivated area to warehouse, and cost of harvesting. The algorithm tested the 18 cases, and five replications tested each case. The results found that the Heuristics Performance of the solutions obtained from the Fractional Knapsack Problem was 99.71% closer to the mathematical model.

Keywords: Long-term crop planning, Fractional knapsack problem, Land use optimization

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Introduction

Agriculture is essential to the economy and well-being of Thailand, and the government also saw the importance of strategy for the country's long-term agricultural development. Currently, agriculture in Thailand has encountered problems because farmers have to cultivate without production planning and regardless of market needs. Many farmers were turning to high-profit crops, which made Thailand less exportable. As a result, owing to the market mechanism, Thailand has products that exceed market demand and lower selling prices. In 2018, The government urged farmers who grow rice to turn to sugarcane cultivation. As a result, sugarcane has more quantity than the demand. Including the selling price lower than cost. Farmers called for the government to help regarding compensation for the loss, pledge of product, price insurance that is not the market price, Bringing the state budget to buy products at market price, which the solutions to these problems cannot sustain. The researcher has seen the problems and importance of the management of cultivated areas and reducing production costs. The biggest problem encountered is that the production of agricultural products is not in line with the market demand, which results in higher cost of cultivation, loss of leads and the pre-harvest management system is not powerful enough, the establishment of a warehouse at an appropriate location and size to help reduce transportation costs. Therefore, it is necessary to manage long-term crop planning to control the quantity of production and the cost to maximize profit.

The problems were as follows: The crops were cultivated together in each plantation area depending on the type of crops, time of cultivation and multiple periods within the year. In this research, using many methods to solve the problems as follows (1) Mathematical modeling of cultivated area allocation and warehouse determination, which the answer will be the best answer and a prototype for finding solutions to minor problems (2) Heuristics by modifying Fractional Knapsack for cultivated area allocation and warehouse determination.

The expected advantages of the research are (1) Obtaining a model for allocation of cultivated area and determining warehouses that are suitable for the nature of the problem by causing the highest profit in production (2) Applying the model to allocate areas or problems that are similar.

Objectives of the study

The objectives of this research were to manage long-term crop planning to control the production quantity and maximize profit, cost of cultivation on cultivated area, cost of opportunity as the crop was cultivated or not, cost of changing crop type on cultivated area, cost of transportation from cultivated area to the warehouse, and cost of harvesting. In this research, develop mathematical model and heuristics approaches to modify Fractional Knapsack Problem Algorithm to find the optimal solution to allocate area and warehouses to maximize profit and compare the efficiency of the results between mathematical model and heuristics.

Literature Review

This research used relevant literature to conduct studies. The researcher started the study from the research related to the allocation of various forms. The problem of LAP was proposed at first by Cooper (1963) [1]. Since that year, many researchers have studied the problem in different ways. Gong, Gen, Yamazaki & Xu (1997) [2] presented a hybrid evolutionary method to solve the MINLP for Capacitated Location Allocation Problem. The result is the method able to find global or near-global locations. Ebery, Krishnamoorthy, Ernst & Boland (2000) [3] presented a new MILP for capacitated multiple allocation hub location problems and algorithm CMAHLP. The result was that those new formulations were weaker than the MILP formulations presented in the review, and algorithm CMAHLP cannot solve more significant hub location problems. Jin, Termansen & Hubacek (2008) [4] presented the Genetic Algorithm to uneven agricultural space planning. The result showed that the GA system forecasts land-use decisions in line with the expert predictions and copes with the dynamics for inter-temporal optimization as humans. Qi & Altinakar (2010) [5] presented a new conceptual framework that incorporates an integrated modeling system with an optimization technique for agricultural land use planning with BMPs (best management practices) placement at the watershed level. The result indicated that Tabu Search provides a flexible optimization methodology to take into account various social and economic constraints and thus provides a participatory platform for incorporating the views of all stakeholders into the decision-making process. Shiripour, Amiri-Aref & Mahdavi (2011) [6] presented the MINLP for the location-allocation problem in the presence of a line barrier with K connections. The aim was to find the optimal locations of a given set of new facilities and the optimal allocations of existing facilities to minimize the total weighted traveled rectilinear barrier distances from the new facilities to the existing ones. The results illustrated that the presence of a line barrier with two connections on the line barrier affected the objective value of the problem and affected the optimum locations and allocations of the new facilities compared with the case without a barrier. Liu et al. (2012) [7] presented a MACO-MLA method that proved to be an efficient and effective optimization technique for generating alternative land-use patterns by altering sub-objective weights. The result showed that the MACO-MLA method might make sense to incorporate as an early planning stage in practical land-use planning. Sethanan (2017) [7] presented the problems in planning to cultivate crops in each area, planning size to cultivate to maximize the profits from the cultivation, which was similar to the problem in this research. Ketsripongsa, Pitakaso, Sethanan & Srivarapongse (2018) [8] presented the methods that solve the allotment of economic crop planning for farmers by improving mathematical models and algorithms Improve DE (I-DE). The results found that the Improve DE (I-DE) can find a better solution than the original DE. Researchers are interested in Pisinger's research, which presents a simple structured algorithm that is easy to modify and apply in research. Pisinger (1995) [9] developed exact algorithms for Knapsack Problems having reasonable solution times for nearly all instances encountered in practice, despite having exponential time bounds for many highly contrived problem instances. The highlight of this research is to modify a simple method to solve the problem quickly and the solution is optimal.

Methodology

Mathematical Model

Planning of cultivation. The model determined that each crop was cultivated in each area and cultivated in which month. Furthermore, the model determined that the crop products of crops in each area were stored in any warehouse when it obtained the products.

The mathematical model for economic crop planning follows.

Indices

i, k stands for crop; i, k = {1, 2, ..., CR}

r stands for round of crop cultivation; r = {1, 2, ..., RND}

j stands for cultivated area; j = {1, 2, ..., LAND}

m stands for cultivated month; m = {1, 2, ..., MON}

w stands for warehouse; w = {1, 2, ..., WH}

Parameters

CR stands for crop

RND stands for the round of crop cultivation

LAND stands for the cultivated area

MON stands for the cultivated month

WH stands for warehouse

P_i stands for the price of crop i *(Baht/Ton)*

$A_{I,j}$ stands for rate of yield that crop I cultivated on area j *(Ton/Rai)*

$L_{i,j}$ stands for crop i that can cultivate on cultivated area j

C_i stands for cultivated cost of crop i *(Baht/Rai)*

G_i stands for opportunity cost that cannot cultivate crop i *(Baht/Ton)*

$E_{k,j}$ stands for crop k that cultivated on area j

H_i stands for the harvesting cost of crop i *(Baht/Rai)*

D_i stands for the demand of crop i *(Ton)*

B_j stands for the maximum size of the cultivated area *(Rai)*

α stands for transportation cost *(Baht/Ton/Kilometer)*

β stands for a large positive number

$F_{i,j,m}$ stands for crop i that can cultivate on area j in cultivated month m

$\gamma_{j,w}$ stands for distance from cultivated area j to warehouse w *(Kilometer)*

$\delta_{i,w}$ stands for crop i that can store in warehouse w

$O_{k,i}$ stands for crop changing cost from crop k to i

V_i stands for processing time of crop i *(Month)*

Decision Variables

$X_{i,j,r,m,w}$ stand for the size of planning cultivated area of crop i on area j in cultivated round r in cultivated month m and send the product to warehouse w

$N_{i,j,m,w}$ stand for the maximum cultivated area size of crop i on area j in cultivated month m and send the product to warehouse w

$T_{i,j,r,m,w}$ stands for the size of planning cultivated area that changes to cultivate crop i on area j in cultivated round r in cultivated month m and send the product to warehouse w

Z_i stand for crop yield that is less than the demand of crop i

Q_w stand for the capacity of warehouse w

$Y_{k,i,j,r,m,w}$ 1, if there is changing crop k to i on area j in cultivated round r in month m and send the product to the warehouse w

0, other cases

$S_{i,j,r,m,w}$ 1, if there is crop i cultivated on area j in month m and send product to warehouse w

0, other cases

$\rho_{k,j,r}$ 1, if there is crop k cultivated on area j round r

0, other cases

Objective Function

Mathematical model designed to maximize profit for crop planning. The related factors considered were crop price, cultivated cost, rate of crop yield, cultivated area size, the opportunity cost that crop yield less than the demand, changing crop type, distance from the cultivated area to the warehouse, and harvesting cost, it expressed as follows:

$$\text{Max} \sum_{i=1}^{CR}\sum_{j=1}^{LAND}\sum_{r=1}^{RND}\sum_{m=1}^{MON}\sum_{w=1}^{WH} P_i A_{i,j} X_{i,j,r,m,w} - \sum_{i=1}^{CR}\sum_{j=1}^{LAND}\sum_{r=1}^{RND}\sum_{m=1}^{MON}\sum_{w=1}^{WH} C_i X_{i,j,r,m,w} - \sum_{i=1}^{CR} G_i Z_i$$
$$- \sum_{k=1}^{CR}\sum_{i=1}^{CR}\sum_{j=1}^{LAND}\sum_{r=1}^{RND}\sum_{m=1}^{MON}\sum_{w=1}^{WH} O_{k,i} T_{i,j,r,m,w} - \alpha \sum_{i=1}^{CR}\sum_{j=1}^{LAND}\sum_{r=1}^{RND}\sum_{m=1}^{MON}\sum_{w=1}^{WH} A_{i,j} X_{i,j,r,m,w}\, \delta_{i,w} \gamma_{j,w}$$
$$- \sum_{i=1}^{CR}\sum_{j=1}^{LAND}\sum_{r=1}^{RND}\sum_{m=1}^{MON}\sum_{w=1}^{WH} H_i X_{i,j,r,m,w} - \sum_{i=1}^{CR}\sum_{j=1}^{LAND}\sum_{r=1}^{RND}\sum_{m=1}^{MON}\sum_{w=1}^{WH} H_i X_{i,j,r,m,w} \quad (1)$$

Constraints

$$N_{i,j,m,w} = \delta_{i,w} B_j L_{i,j} F_{i,j,m} \; ; \forall i, \forall j, \forall w, \forall m \quad (2)$$

$$\rho_{k,j,r} = E_{k,j} \; ; \forall k, \forall j, r = 1 \quad (3)$$

$$S_{i,j,r,m,w} = 1 \; ; \forall i, \forall m, \forall w, \forall j, \forall r, X_{i,j,r,m,w} > 0 \quad (4)$$

$$X_{i,j,r,m,w} \leq N_{i,j,m,w} \; ; \; \forall i, \; \forall m \mid m = r(V_i-1), \; \forall w, \forall k, \forall j, \forall r \tag{5}$$

$$\rho_{k,j,r} = 1 \; ; \; S_{i,j,r,m,w} = 1 \; , \; \forall i, \; \forall m, \; \forall w, \forall k, \forall j, \forall r \tag{6}$$

$$X_{i,j,r,m,w} = 0 \; ; \; \forall i, \; \forall m \mid m \neq r(V_i-1), \; \forall w, \forall k, \forall j, \forall r \tag{7}$$

$$\sum_{i=1}^{CR} \sum_{j=1}^{LAND} \sum_{r=1}^{RND} \sum_{m=1}^{MON} A_{i,j} X_{i,j,r,m,w} \leq Q_w \; ; \; \forall w \tag{8}$$

$$\sum_{j=1}^{LAND} \sum_{r=1}^{RND} \sum_{m=1}^{MON} \sum_{w=1}^{WH} A_{i,j} X_{i,j,r,m,w} \leq D_i \; ; \; \forall i \tag{9}$$

$$\sum_{w=1}^{WH} X_{i,j,r,m,w} \leq B_j \; ; \; \forall i, \; \forall m, \forall j, \forall r \tag{10}$$

$$\sum_{i=1}^{CR} \sum_{w=1}^{WH} X_{i,j,r,m,w} \leq B_j \; ; \; \forall m, \forall j, \forall r \tag{11}$$

$$Y_{k,i,j,r,m,w} \geq S_{i,j,r,m,w} + \rho_{k,j,r} - 1 \; ; \; \forall i \mid i \neq k, \; \forall m, \; \forall w, \forall k, \forall j, \forall r \tag{12}$$

$$T_{i,j,r,m,w} \leq X_{i,j,r,m,w} \; ; \; \forall i, \forall j, \forall r, \forall m, \forall w \tag{13}$$

$$T_{i,j,r,m,w} \leq \beta * Y_{k,i,j,r,m,w} \; ; \; \forall i, \forall j, \forall r, \forall m, \forall w, \; \forall k \mid i \neq k \tag{14}$$

$$T_{i,j,r,m,w} \geq X_{i,j,r,m,w} - \beta * (1 - Y_{k,i,j,r,m,w}) ; \; \forall i, \forall j, \forall r, \forall m, \forall w, \; \forall k \mid i \neq k \tag{15}$$

$$T_{i,j,r,m,w} \geq 0 \; ; \; \forall i, \forall j, \forall r, \forall m, \forall w \tag{16}$$

$$Z_i = D_i - \sum_{j=1}^{LAND} \sum_{r=1}^{RND} \sum_{m=1}^{MON} \sum_{w=1}^{WH} A_{i,j} X_{i,j,r,m,w} \; ; \; \forall i \tag{17}$$

$$Z_i, Q_w, X_{i,j,r,m,w}, \varepsilon_{i,j,r,m}, N_{i,j,m,w}, \geq 0 \; ; \; \forall i, \; \forall j, \; \forall r, \; \forall m, \; \forall w \tag{18}$$

$$S_{i,j,r,m,w}, Y_{k,i,j,r,m,w} \in \{0,1\} \; ; \; \forall i, \forall j, \forall r, \forall m, \forall w, \forall k \tag{19}$$

The mathematical model shown above can be described as following: Equation (1) is an objective function focused on maximizing profit which consists of six primary sequences: Sequence (1) is a function of revenue from selling crops; Sequence (2) is a function of cultivated cost; Sequence (3) is a function of opportunity cost that crop yield less than the demand; Sequence (4) is a function of changing cultivated crops on the cultivated area; Sequence (5) is a function of transportation from cultivated area to warehouse; Sequence (6) is a function of harvesting cost. Equation (2) is the maximum cultivated area size of crop i on area j in cultivated month m and transport to warehouse w. Equation (3) is the setting of starting crop k on cultivated area j. Equation (4) if the size of planning cultivated area is more than zero, $S_{i,j,r,m,w} = 1$. Equation (5) is the size of planning cultivated area in the cultivated month cannot exceed the maximum cultivated area size of crop i on area j in cultivated month m and transport to warehouse w. Equation (6) is the setting of starting crop on the cultivated area when the size of the planning cultivated area is more than zero. Equation (7) is the size of planning cultivated area that is not in the cultivated month is zero. Equation (8) is a limit of crop yield that cannot exceed the capacity of the warehouse. Equation (9) is a limit of crop yield that cannot exceed the demand for the crop. Equation (10) is a limit of planning cultivated area size of crop i on area j cultivated round r in month m and transport to warehouse w that cannot exceed the maximum size of the cultivated area. Equation (11) is a limit of planning cultivated area j in cultivated round r in month m and transport to warehouse w for all crop i that cannot exceed the maximum size of the cultivated area. Equation (12) if crop on the planning cultivated area has changed, $Y_{k,i,j,r,m}=1$. From the objective function, There are two decision variables ($X_{i,j,r,m}$, $Y_{k,i,j,r,m}$) to multiply each other. Thus, resulting in Non-Linear programming. Therefore it must be Linear programming by defining upper bound as Equation (13), (14) and lower bound as Equation (15), (16). Equation (17) is a crop yield that is less than the demand for crop i, Equation (18) are decision variables that must not be less than zero. Equation (19) are decision variables that must be zero or one only.

During the cultivation of the economic crops, considering the allocation of cultivated land in each area can grow many crops, each crop can be cultivated for many periods, Considering the types of crops that cannot be grown together in each area, considering long-term crop planning to control the quantity of the product and the cost to maximize profit. Figure 1 shows the model of cultivation in areas and transport products to store in the warehouses.

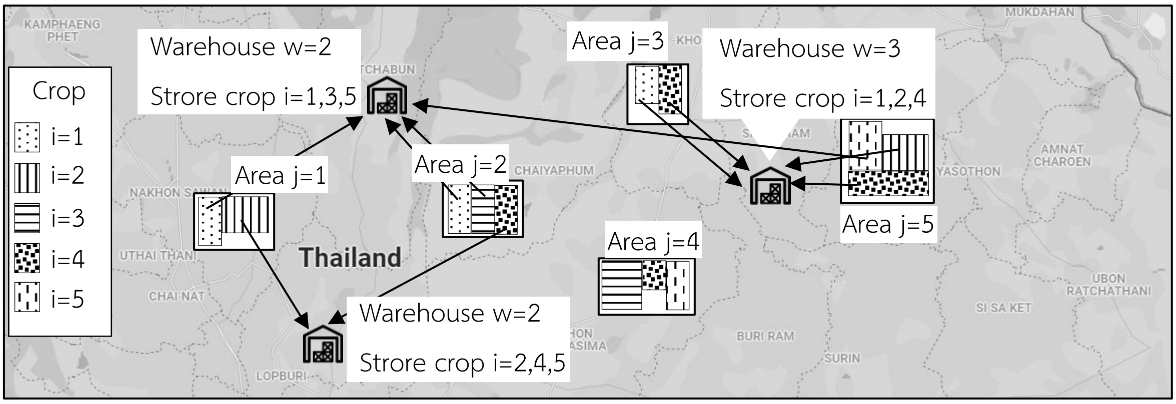

Figure 1 the model of cultivation in areas and transport products to store in the warehouses

Validation

Assign 3 cultivated crops, 10 cultivated areas, 7 warehouses, and 60 cultivated months. After developing mathematical model using Gurobi Optimization Solver program, the experimental result is shown in Figure 2. The answer can be shown in details as follows: (1) total profit 408,434,661,084.61 Baht includes revenue 1,017,000,000,000.00 Baht, cultivated cost 469,406,147,674.42 Baht, opportunity cost 0 Baht, changing cultivated crops 692,878,104.20 Baht, transportation cost 92,218,576,473.52 Baht, and harvesting cost 46,247,736,663.24 Baht (2) Plan of cultivation of crop for each cultivated month is shown in Figure 3.

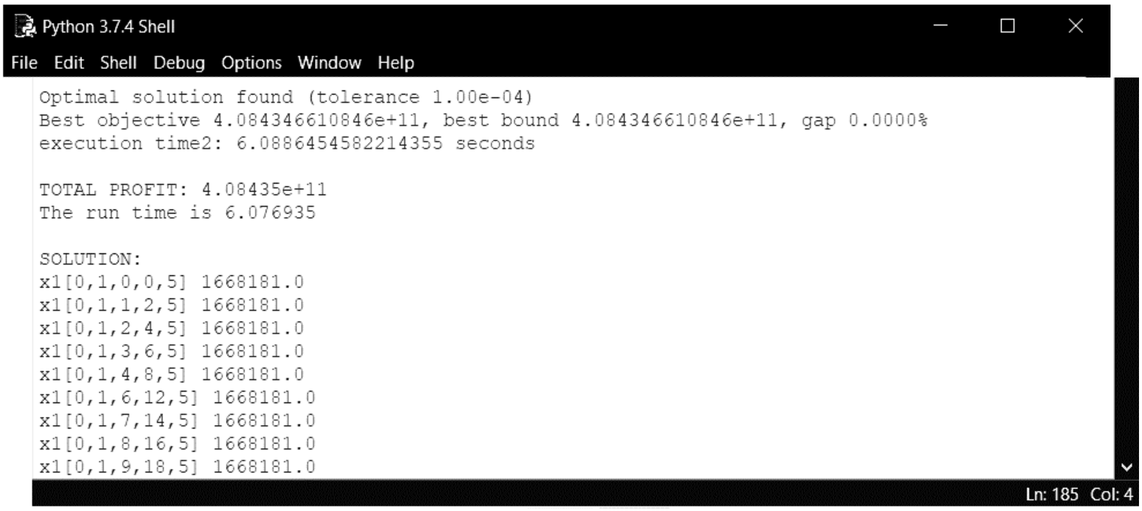

Figure 2 the experimental result

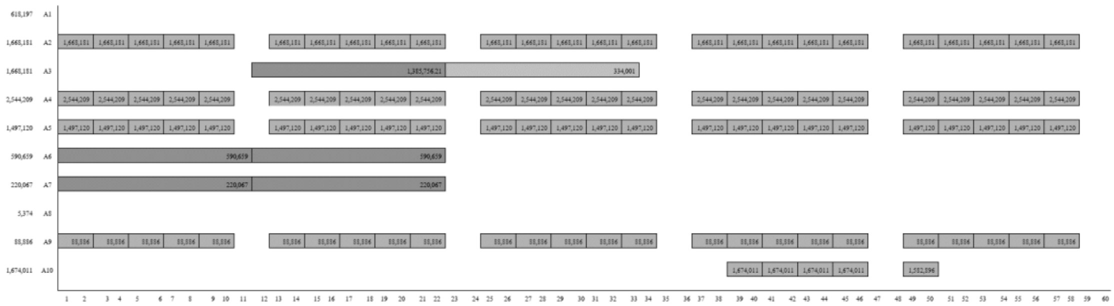

Figure 3 Plan of cultivation of crop for each cultivated month

Fractional Knapsack Problem

This research developed Knapsack Problem algorithms to search for the exact solution in the NP-Hard problem. Knapsack problems required a subset of some given items to choose such maximized corresponding profit sum without exceeding the capacity of the knapsacks. The researcher chose this method because of the simple structure of the algorithm; problems could be solved quickly and could easily modify the algorithm. The algorithm chose the cultivated area that maximized initial profit, calculated from revenue, cultivated cost, harvesting cost, and transportation cost. In terms of weight, it was calculated from the yield of each cultivated area. Then, the fraction would calculate between the profits and the weight of each cultivated area to consider the maximum fraction and select that cultivated area.

Fractional Knapsack Problem algorithms

Algorithm 1 Modifying Fractional Knapsack Algorithm for allocation of cultivated area and determining warehouses

input: $i \in CR$, $j \in LAND$, D_i, $m \in MON$, $w \in WH$

output: fraction $FT_{i,j}$ of each cultivated area that maximizes profit

Begin
For crop $i \in CR$
    Demand=D_i
    For cultivated area $j \in LAND$
    Calculate profit and product $Profit_{i,j}$, $Weight_{i,j}$ of each cultivated area
    Set $FT_{i,j}$=0, $Valuet_{i,j}=\frac{Profit_{i,j}}{Weight_{i,j}}$, Demand=$D_i$
    While Demand $\leq D_i$
        Choose cultivated area j that has a maximum of $Value_{i,j}$
            If $Weight_{i,j} \leq$ Demand
                $FT_{i,j} = 1$
            Else
                $FT_{i,j} = \frac{Demand}{Weight_{i,j}}$
            Demand$\longleftarrow$Demand-$Weight_{i,j}$
            For month $m \in MON$
                IF $F_{i,j,m}$=1 and $L_{i,j}$
$FTM_{I,j,m} = FT_{I,j}$
                    m=m+V_i
                ELSE
                    m=m+1
                Find warehouse w that can store crop i and nearest cultivated area j
                $X_{i,j,m,w} \leftarrow FTM_{i,j,m}$
            End For
    End For
End For
End

Results

The computational results are the comparison of the Fractional Knapsack Problem Algorithm (FKP) with the result generated by Gurobi Python API (mathematical solver) is presented to check if the proposed heuristics are reliable and trustable.

Python 3.7 was used to design the algorithm of FKP to compare the result with the processing unit (Intel® Core™ i7-7500 2.7 GHz and 16 GB memory). The problem instances were categorized into three groups: (1) Small-sized instances, (2) Medium-sized instances, (3) Large-sized instances. The experimental design of this research is the factorial design, which consider the factors that affecting the objective function is the number of cultivated area and crops. Cultivated areas are divided into three levels as follows: (1) Low 5-9 areas, (2) Medium 10-15 areas, (3) High 16-20 areas. Crops are divided into two levels: (1) 1-3 crops, (2) 4-6 crops. There are three samples used in the experiment in each case, and five replications tested each case. The results of FKP compared with Gurobi Python API are shown in Table 1.

Table 1 The results of the Fractional Knapsack Problem compared with Gurobi Python API

Problem group	Areas	Crops	Methods			
			Gurobi		FKP (Average)	
			Solution (Baht)	Time (s)	Solution (Baht)	Time (s)
Small size	5	1	3.85×10^{11}	7.20	3.85×10^{11}	1.18
	7	2	3.87×10^{11}	47.19	3.87×10^{11}	1.65
	9	3	3.94×10^{11}	245.33	3.94×10^{11}	2.34
	5	4	8.14×10^{11}	211.37	8.05×10^{11}	1.74
	7	5	7.29×10^{11}	793.76	7.29×10^{11}	2.35
	9	6	7.36×10^{11}	2,597.94	7.36×10^{11}	3.00
Medium size	10	1	3.97×10^{11}	16.61	3.97×10^{11}	1.63
	13	5	3.98×10^{11}	135.46	3.98×10^{11}	2.39
	15	3	4.05×10^{11}	647.01	4.05×10^{11}	3.08
	10	4	8.52×10^{11}	787.57	8.35×10^{11}	2.36
	13	5	1.30×10^{12}	2,730.60	1.28×10^{12}	3.01
	10	6	1.23×10^{12}	7,864.46	1.23×10^{12}	5.12
Large size	16	1	4.00×10^{11}	35.22	4.00×10^{11}	1.94
	18	2	4.00×10^{11}	251.56	4.00×10^{11}	3.12
	20	3	4.06×10^{11}	1,138.21	4.06×10^{11}	3.11
	16	4	8.55×10^{11}	1,969.89	8.55×10^{11}	3.81
	18	5	1.24×10^{12}	5,464.98	1.23×10^{12}	5.13
	20	6	1.24×10^{12}	12,372.65	1.23×10^{12}	6.11

In terms of computational time, the biggest problem will take more time to compute. When comparing the computational time between FKP and Gurobi, the results indicated that Gurobi took more time than FKP. The results from Table 1 showed that FKP was faster than the Mathematical model.

Using the Heuristics Performance of the solutions to compare FKP and Gurobi by calculating from Equation (20). The results are shown in Figure 4.

$$\%HP = \frac{\text{the result from FKP method}}{\text{the result from Gurobi}} \times 100\% \qquad (20)$$

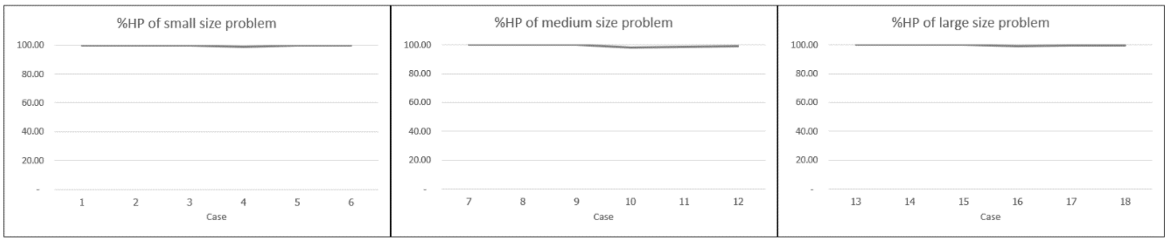

Figure 4 %HP of small-size, medium-size, and large-size problems

The results found that the Heuristics Performance of the solutions obtained from the Fractional Knapsack Problem was 99.71% closer to the mathematical model.

The Statistical analysis results using Paired Samples T-Test method are shown in Figure 5

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	MILP - FPK	2959150076	6246994119	1472430635	-147407014	6065707166	2.010	17	.061

Figure 5 Statistical analysis result

The statistical analysis result determines the effectiveness of the Fractional Knapsack Problem compared to the mathematical model. The result found that the Fractional Knapsack Problem Algorithm and the mathematical model were not significantly different at 95% confidence interval, which meant that the Fractional Knapsack Problem was as effective as the mathematical model.

The results showed that the mathematical model was suitable for solving small and medium-size problems because it was the best solution method and did not take too much computational time. The FKP method is suitable for solving large-size problems because the solution from FKP is close to the mathematical model, and FPK takes less computational time than the mathematical model.

There were limitations in this research as follows: (1) Each cultivated area is cultivated many types of crops, (2) Each type of crops are cultivated in many periods, (3) Some crops are cultivated together, (4) Each warehouse could store every crop type, (5) The profit calculated from revenue, cultivated cost, opportunity cost, changing cultivated crop cost, harvesting cost, and transportation cost.

The research for finding an optimal method to allocate cultivated areas and determine warehouses found that FKP is the effective method, and the results are close to the exact solution. It also took less time to compute when comparing with the mathematical model. It helps the government's cultivation plan quickly and sets farmers' cultivation policies to solve problems that exceed the demand properly.

Discussion and Conclusions

This research was a study on long-term plant allocation problems and warehouse determination by considering the limitations of the type of plants that can be grown in each area and stored in each warehouse. This research aimed to allocate the cultivated area and maximize the profits of revenue after deducting the planting cost, opportunity cost caused by insufficient production to meet the market demand, changing cost, harvesting cost, and transportation cost.

This problem was solved by (1) Formulating a mathematical model as Mixed Integer Linear Programming (MILP) to find the optimal solution for small-sized problems, (2) Providing a method for searching for an optimal solution using the Fractional Knapsack Problem (FKP) in large-sized problems..

The study results found that the Heuristics Performance of the solutions obtained from the Fractional Knapsack Problem was 99.71% closer to the mathematical model. The statistical analysis result determined the effectiveness of the Fractional Knapsack Problem comparing to the mathematical model found that the solution from Fractional Knapsack Problem and the mathematical model were not significantly different at 95% of the confidence interval, it meant that the Fractional Knapsack Problem was as effective as the mathematical model.

Future research should focus on determining the optimal warehouse location and develop the metaheuristics such as Genetic Algorithm (GA) or Variable Neighborhood Search (VNS) or other techniques for searching the solutions.

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