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OPTIMATION OF AGRICULTURAL LAND WITH THE HUNGARIAN ALGORITHM METHOD (CASE STUDY: AGRICULTURAL LAND IN TUATUKA VILLAGE, KUPANG REGENCY)

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ABSTRACT

This research delves into how the Hungarian Algorithm's utilized to streamline workforce allocation, for activities in Tuatuka Village located in Kupang Regency in East Nusa Tenggara region of Indonesia. The primary obstacles encountered include shortage of labor and differences, in skill levels that affect productivity levels significantly. By employing the Hungarian Algorithm a mathematical method is utilized to reduce costs and time associated with assigning tasks effectively by matching workers to duties based on their skills and capabilities. This study includes gathering data by observing and conducting interviews that are later examined using POM QM, for Windows V5 software and manual computations. The results indicate that implementing this method can cut down total project expenses to 35 work hours through task allocation strategies. The adoption of the Hungarian Algorithm has been successful in improving workforce efficiency in agriculture areas leading to output. Decreased resource wastage. Therefore this study aids, in streamlining operations in the industry especially when it comes to managing resources in rural settings.

Keywords : Task Optimization, Hungarian Algorithm

I. INTRODUCTION

Agricultural land is land which is suitable for agricultural activities, either for producing crops or raising livestock. It is also one of the primary resources in agricultural activities[1]. Indonesia, as an agrarian country, relies heavily on agricultural land, which holds strategic importance for its people, serving not only economic functions but also social and religious roles[2]. Agricultural land can be distinguished by physical form and ecosystem, categorized into wetland and dryland. Examples of agricultural land use include rice fields, dry fields, gardens, grasslands, forests, and savannas[3]. Resources used in agricultural land management include fertilizers, pesticides, and agricultural tools and machinery (ALSINTAN).

Agricultural land plays a crucial role in the economy of Indonesian communities, especially in regions that depend on the agrarian sector, such as Kupang Regency in East Nusa Tenggara Province [4]. Tuatuka Village, located within Kupang Regency, has significant agricultural potential. However, like agricultural areas elsewhere, the agricultural land in Tuatuka faces various resource management challenges. One of the main challenges is effective workforce management, particularly in activities such as planting, fertilizing, spraying, and harvesting. Limited workforce availability and varied skill levels among workers are factors that often restrict land productivity.

In the agricultural land of Tuatuka Village, the primary issue is how to optimize the assignment of available labor across various tasks, considering their skills and capacities while adjusting to external factors such as weather conditions and the availability of farming tools.

To address this issue, the Hungarian algorithm offers a mathematical approach to optimizing workforce assignments to various tasks on agricultural land. This algorithm is designed to solve assignment problems with the goal of minimizing costs or maximizing efficiency by allocating workers to tasks that best match their skills and capacities. By using this method, the agricultural land in Tuatuka Village can maximize productivity by utilizing existing resources efficiently. Therefore, this research aims to develop a workforce assignment model that can optimize land productivity by minimizing resource wastage.

II. METHODS

2.1. Research Procedure

This research was conducted at an agricultural site in Tuatuka Village, East Kupang District, East Nusa Tenggara. Data collection techniques included several methods:

a) Observation to monitor various operational activities [5] involving labor and the use of agricultural equepment.

b) Interviews with key stakeholders on the farm, including landowners and workers.

The necessary data for this research includes:

a. Types of crops on the agricultural land,

b. Types of jobs on the farm,

c. Number of workers on the farm,
d. Distribution of labor across activities, such as planting, fertilizing, spraying, and harvesting,
e. Availability and usage of agricultural tools, such as tractors, sprayers, etc.,
f. Time required for each field task to understand time allocation and potential resource waste.

The data collected by researchers is then analyzed using the POM-QM application to help determine the optimal assignment results for the agricultural site.

2.2. Method

2.2.1. Assignment Algorithm Model (Hungarian Algorithm)

The assignment algorithm model is designed to solve assignment problems by modifying the cost or effectiveness matrix, thereby finding an optimal solution that minimizes total cost. This method works by adjusting elements within the rows and columns of the matrix until a single zero solution is obtained in each row or column, which can then be selected as the optimal allocation for assignments. The steps for solving assignment problems using the Hungarian method are [6]:

Step 1:

- Find the smallest element in each original cost row matrix.
- Create a new matrix by subtracting each row element from smallest row element.
- Then do the same for each column in the new matrix, subtract the smallest element in each column from each element in that column, and you have the reduced cost matrix.

Step 2:

- Draw the minimum number of lines (horizontal or vertical) to cover all zeros in the reduced cost matrix.
- The optimum solution has been found if the number of lines required equals the number of workers or tasks (m or n).

Step 3:

- Find the smallest non-zero element in the cost matrix for which there is no row.
- Subtract this element from all uncovered elements. Add it to elements covered by two lines.
- Return to Step 2 and repeat until the optimum solution is found where all tasks can be optimally allocated.

The Hungarian method efficiently solves assignment problems through gradual reduction in the cost matrix and calculates optimal allocations based on these modifications. This method allows each task to be assigned to the most suitable worker at minimal cost or time.

2.2.2. Assignment Problem

The assignment problem is a type of optimization problem which aims to determine the allocation of resources (workers or objects) to a set of tasks (activities) in a cost- or time-minimizing manner [7]. In this context, each worker is assigned a specific task to complete, with each task incurring different costs depending on who performs it.

The primary goal in assignment problems is to find a combination of allocations that results in the lowest total cost or the most efficient time[8].

Generally, assignment can be defined with the following mathematical notation:

- Workers (m): Total available workforce.
- Tasks (n): Total tasks or activities to be completed.
- Assignment (X_{ij}): A binary variable indicating whether worker i is assigned to task j (X_{ij} = 1 if worker i is assigned to task j, X_{ij} = 0 if worker j is not assigned to task j).
- Allocation parameter (C_{ij}): The cost or time taken by worker i to complete task j.

By minimising the objective function (Z), which represents the total assignment cost or time, the mathematical model of the assignment problem is formulated as follows:

Minimize :

$$Z = \sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij}X_{ij} \quad \text{.....(1)}$$

With obstacles :

$$\sum_{j=1}^{n} X_{ij} = 1 \quad \forall\ i = 1, 2, \ldots, m \text{ (Kendala baris)}$$

$$\sum_{i=1}^{m} X_{ij} = 1 \quad \forall j = 1, 2, \ldots, n \text{ (Kendala kolom)}$$

$X_{ij} \in \{0,1\}\ \forall\ i,j$

Explanation:

Z : The objective is to find the optimal value (the maximum or the minimum) of this function.

N : Total tasks to complete.

X_{ij}: Assignment from the source (worker) *i* to the target (task) *j*.

C_{ij}: This notation represents the allocation parameter from source *i* to target *j*.

- Each worker can only handle one task.
- Each task must be allocated to one worker.

This notation shows that the optimisation goal is the determination of the assignment that gives the optimal value of the objective function (Z), minimizing total cost or time to complete all tasks assigned [9].

The matrix model used to solve assignment problems using the Hungarian algorithm is as follows:

Task / Worker	Worker 1	Worker 2	Worker 3	Worker 4	Worker 5	Worker 6
Task 1	C11	C12	C13	C14	C15	C16
Task 2	C21	C22	C23	C24	C25	C26
Task 3	C31	C32	C33	C34	C35	C36
Task 4	C41	C42	C43	C44	C45	C46
Task 5	C51	C52	C53	C54	C55	C56
Task 6	C61	C62	C63	C64	C65	C66

Figure 1 : Hungarian Algorithm Matrix

Explanation:

- **Cij** represents the cost or time required by Worker *i* to complete Task *j*.
- This matrix can be filled with actual values obtained from observations or interviews.

This matrix contains the costs or time needed by workers to complete a given task [10].

III. RESULTS AND DISCUSSION

3.1. Result

3.1.1. Manual Calculation Results with the Hungarian Algorithm

In this research, the labor assignment problem on agricultural land was solved using the Hungarian method to minimize the total labor cost. Labor assignment cost data for various tasks on farmland in Tuatuka Village was obtained through field observation and then processed into a cost matrix. For example, using the following cost matrix consisting of 6 workers and 6 tasks.

Table 1 : Initial Cost Matrix

Task/worker	Gus	Novi	Yunus	Yanti	Meki	Nona
Land Preparation	8	8	8	6	8	6
Planting	3	3	3	1	3	1
Spraying	7	7	7	5	10	8
Fertilizing	7	7	7	5	7	5
Harvesting	7	7	7	5	7	5
Irrigation	7	7	7	5	7	5

(Data Source: Agricultural Land in Tuatuka Village, Kupang Regency)

Table 2 : Row Reduction

Task/worker	Gus	Novi	Yunus	Yanti	Meki	Nona
Land Preparation	2	2	2	0	2	0
Planting	2	2	2	0	2	0
Spraying	2	2	2	0	5	3
Fertilizing	2	2	2	0	2	0
Harvesting	2	2	2	0	2	0

Irrigation	2	2	2	0	2	0

(Data Source: Agricultural Land in Tuatuka Village, Kupang Regency)

Table 3 : Column Reduction

Task/worker	Gus	Novi	Yunus	Yanti	Meki	Nona
Land Preparation	0	0	0	0	0	0
Planting	0	0	0	0	0	0
Spraying	0	0	0	0	2	3
Fertilizing	0	0	0	0	0	0
Harvesting	0	0	0	0	0	0
Irrigation	0	0	0	0	0	0

(Data source: Agricultural Land in Tuatuka Village, Kupang Regency)

After the steps of row reduction, column reduction, and matrix adjustments, the optimal assignment results are as follows:

Table 4 : Optimal Assignment

Worker	Assigned Task	Assignment Cost
Gus	Spraying	3
Novi	Fertilizing	5
Yunus	Harvesting	7
Yanti	Planting	7
Meki	Irrigation	7
Nona	Land Preparation	6

(Data source: Agricultural Land in Tuatuka Village, Kupang Regency)

From these results, the total labor assignment cost is 3+5+7+7+7+6 = 35. The Hungarian method's assigment ensures each worker is optimally allocated to a task, minimising overall cost.

3.1.2. Calculation Results Using POM-QM for Windows V5

In addition to manual calculations, the POM-QM For Windows V5 application was also used to verify the calculation results. Entering data into the cost matrix within this application allows for faster and more accurate calculations. The steps are as follows:

1. Activate the POM-QM for Windows V5 application, then select the Assignment module, as shown in the Figure 1.

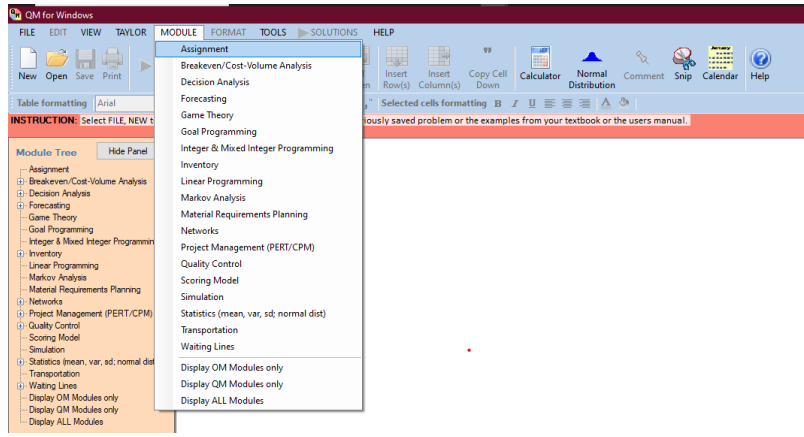

Figure 1: POM-QM Program Initial Display

2. Enter all data in the matrix into the application, as shown below:

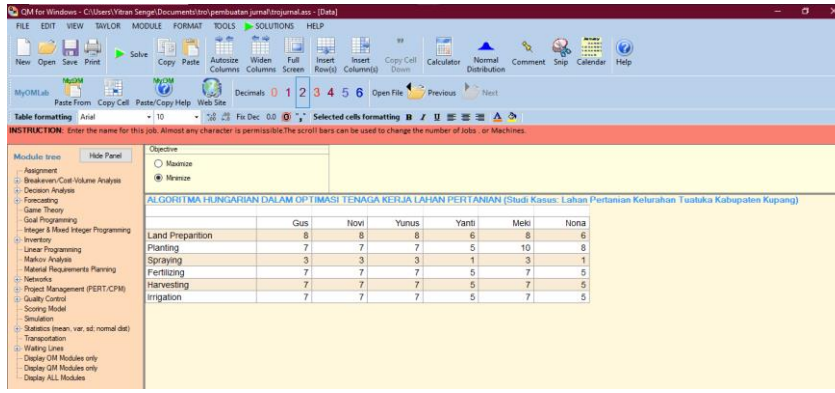

Figure 2 : POM-QM Data Table

3. Analyze the data entered using the "Solve" button to obtain the optimal solution and total cost, as shown in Figure 3.

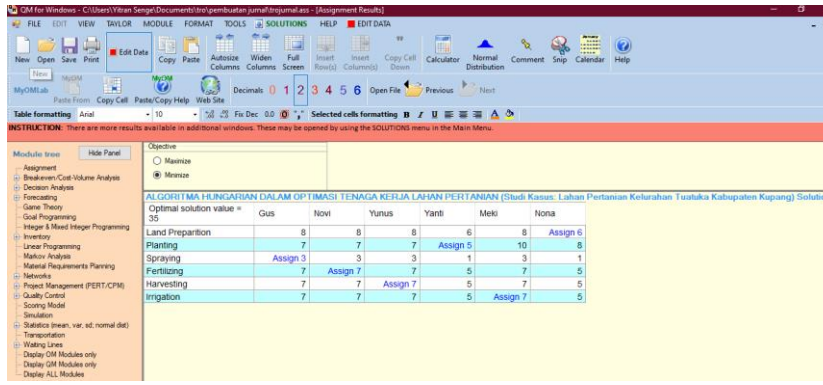

Figure 3 : Optimal Assignment Solution and Total Cost Value

3.2. Discussion

Based on the results of the Hungarian algorithm calculations carried out manually and using the POM-QM For Windows V5 application for allocation tasks on agricultural land in Tuatuka village, Kupang Regency, we can observe an optimal allocation that gives a total optimal value of 35 hours.This optimization process aims to assign six workers (Gus, Novi, Yunus, Yanti, Meki, and Nona) to six different jobs (Land Preparation, Planting, Spraying, Fertilizing, Harvesting, and Irrigation) with the objective of minimizing labor cost or time.

The optimal assignments derived from the matrix table are as follows:

- Land Preparation is assigned to Nona with a minimum cost or time value of 6 hours.
- Planting is assigned to Yunus with a minimum cost or time value of 7 hours.
- Spraying is assigned to Novi with a minimum cost or time value of 3 hours.
- Fertilizing is assigned to Yanti with a minimum cost or time value of 5 hours.
- Harvesting is assigned to Gus with a minimum cost or time value of 7 hours.
- Irrigation is assigned to Meki with a minimum cost or time value of 7 hours.

This allocation process follows the steps of the Hungarian method, modifying the cost/task matrix to result in a single zero in each row and column, indicating the optimal allocation. Each worker is given a task suited to their optimal capacity, minimizing total operational costs.

The optimal result with a total value of 35 demonstrates that task distribution has been done efficiently, with no task assigned to more than one worker or duplicated, and each task optimally filled by one worker.

IV. CONCLUTION

This research successfully addressed the assignment problem on agricultural land using the Hungarian Algorithm, implemented through the POM-QM For Windows V5 software and manual calculations. The assignment process carried out with this algorithm aimed to minimise the cost or time required to complete various tasks on the agricultural land, resulting in an optimal assignment of a total of 35 working hours.

The results suggest that the Hungarian method is an effective way to solve assignment problems in complex work settings such as agricultural land. Using POM-QM makes calculations easier and ensures that optimum assignment results are accurate. This study also demonstrates that optimizing labor assignments is essential for enhancing operational efficiency in the agricultural sector, leading to more precise and measurable resource allocation.

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