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OPTIMIZATION OF WATER RESOURCES UTILIZATION DISTRIBUTION FOR AGRICULTURAL BENEFITS IN THE CLAMPIS IRRIGATION AREA SAMPANG DISTRICT

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ABSTRACT
Utilization of water resources and management is an important factor and has a decisive role in order to increase production per plant in general and crop production in particular. In order to maintain self-sufficiency in food, it is necessary to make efforts to continuously increase the intensity of potential food crops. These efforts include optimizing the proper distribution of water utilization. Factors to determine the need for irrigation water include land preparation, consumptive use, percolation and seepage, replacement of water layers, and effective rainfall. While the method used in this study is optimization using a linear program using the Solver facility in Microsoft Excel with the aim of optimizing the availability of irrigation water so as to produce maximum profits and distribution of irrigation utilization that is more effective and efficient. From the optimization results using the Solver and Microsoft Excel tools, it can be seen that the maximum area of land that can be planted with the available inflow at the intake for MTI (Rice I 2086 Ha/Tobacco II 667.54 Ha), MT-II (Rice I 667, 54 Ha/Tobacco I 1391 Ha/PolowijoI 567.35 Ha/Rice II 128.11 Ha), MT III (Polowijo I 323.65 Ha/Rice II 348.89 Ha/Tobacco II 1261.46 Ha/Polowijo II 825, 00) and provides an analysis of the maximum profit of agricultural products of Rp. 178,183,800,000.00,-.

Keywords: *Linear Program Optimization; Utilization of Water Resources; Agricultural Benefits; Klampis Irrigation.*

1. Introduction

Utilization of water resources and management is an important factor and has a decisive role in order to increase production per plant in general and crop production in particular. In line with the rate of population growth, efforts are made to increase food production through efforts to increase production yields in agricultural areas. With this in mind, in addition to developing water resources, it is necessary to increase the efficiency of its use, especially the use of water for agricultural irrigation purposes.

Availability of water both now and in the future is very important in supporting the development of a region. The limited availability of water and the level of demand that is getting bigger and bigger will have the potential to cause conflicts over the desire to control water resources in various sectors and interests. The availability of water in the agricultural sector is one of the most important and absolutely necessary components for plants. One way of fulfilling water demand services for the agricultural sector is through the irrigation system.

This study took place in the Klampis Irrigation Area which is located in Kramat Village, Kedungdung District, Sampang Regency, Madura, East Java, Indonesia. The Klampis Irrigation Area which has a channel length of 32,119 km and an area of 2,754 Ha of Baku Paddy Fields (Source UPT PSDAWS Madura Service).

In order to maintain self-sufficiency in food, it is necessary to make efforts to continuously increase the intensity of potential food crops. These efforts include optimizing the proper distribution of water use. This can be overcome by one of them with optimization techniques. Optimization is intended to optimize the availability of irrigation water so as to produce agricultural production and maximum profit as well as the distribution of irrigation utilization can be more efficient and effective, so that the Klampis Irrigation Regional Irrigation Network can function optimally as planned, namely to be able to meet the water needs of farmers in the area.

2. Material and Methods

This study took place in the Klampis Irrigation Area which is located in Kramat Village, Kedungdung District, Sampang Regency, Madura, East Java, Indonesia. The Klampis Irrigation Area which has a channel length of 32,119 km and an area of 2,754 Ha of Baku Paddy Fields (Source UPT PSDAWS Madura Service).

Figure 1. Mapping of the Klampis Reservoir

2.1. Required Data

The data needed in this study are as follows:

1. Rainfall Data
   Rainfall data used is secondary rainfall for the last 10 years.
2. Debit Data
   The discharge data used is the intake discharge data at the Klampis Dam for the last 10 years
3. Climatological data
   The data used are temperature data, relative humidity data, wind speed data, and solar brightness data.
4. Irrigation Data
   This data includes the standard area of paddy fields, and types of plants.
5. Economic Data
   This data is in the form of data on agricultural production in rupiah per Ha.

2.2. Study Step

The study steps must be arranged in such a way that they constitute a systematic arrangement for conducting analysis in finding solutions to existing problems. The study steps in carrying out this final project are as follows:

1. Calculating potential evapotranspiration using the Modified Penman Method
2. Determine the effective rainfall
3. Calculating the water needs of plants
4. Analysis of debits to obtain reliable debits
5. Determine the formulation of the Linear Program model
6. Analyzing the Optimization study with the Solver Program

Vol. 4, No. 1, pp. 37-46, March 2023
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2.3. Data Processing

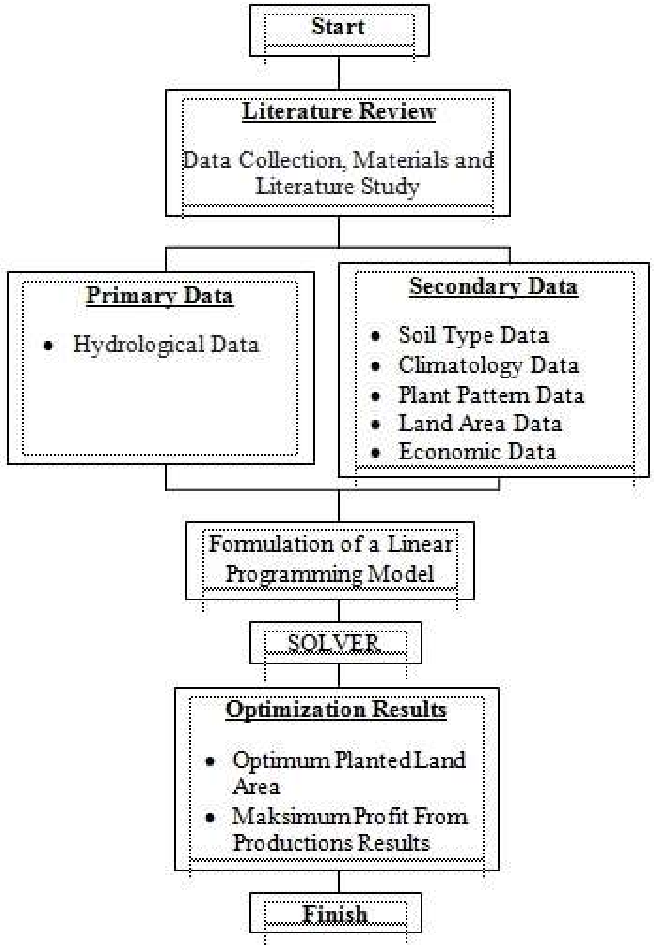

Figure 2. Research Flowchart

3. Result and Discussion

3.1. Definition of Irrigation

According to Hansen, Irrigation is an effort to provide, regulate and develop irrigation water to support agriculture which types include surface irrigation, swamp irrigation, underground water irrigation, pump irrigation, and pond irrigation [1].

The irrigation system includes irrigation infrastructure, irrigation water, irrigation management, irrigation management institutions, and human resources. Provision of irrigation water is the determination of the volume of water per unit of time allocated from a water source to an irrigation area based on time, quantity, and quality according to the need to support agriculture and other needs [3].

3.2. Irrigation Water

According to Mawardi, water is an important factor in farming. In addition to the type of plant, the water requirement for a plant is also influenced by the nature and type of soil, climatic conditions, soil fertility, farming methods, planting area, topography, growing period, and so on. Irrigation water is used for rice, secondary crops, sugar cane, fruits, and grass [3]. Rice is not an aquatic plant, but for its life it needs water. In determining the need for water for plants there are ways:

Vol. 4, No. 1, pp. 37-46, March 2023
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1. According to the height of water needed for a plot of land planted or the amount of water equal to the height of water needed multiplied by the area of the land.
2. The amount of water needed in a unit area for one watering or during its growth, or A m3 per hectare.
3. The unit of water flow, namely the contents in the unit of time of flow for a unit area (liters/second/hectare)
4. Determine the area of plants that can be irrigated by a certain amount of water flow.
   How to use water depends on the conditions of irrigation, soil, plants watered, and so on. How to use water can be divided into several parts, namely soaking the soil, seeping water, draining and drying, wetting in the soil, watering and spraying. Soaking the soil with a renewal of water is commonly used in rice cultivation.

In increasing food production, irrigation has an important role, namely to provide water for plants and can be used to regulate soil inertia, help fertilize the soil through materials containing sediment carried by water, can suppress the development of certain pests and diseases, and facilitate soil processing.

3.3 Mainstay Debit

A mainstay debit is a debit that occurs or is fulfilled within a certain period of time. This reliable discharge is used as the basis for planning the water level. In accordance with the need for water for irrigation, the mainstay debit used is the mainstay discharge of 80%.

The mainstay discharge method used in this study is the Weibull probability method, the steps are as follows:

1. Calculate the average debit of 10 days for 10 years of available debit data, using the formula:

$$X = (X1 + X2 + X3 + ... + Xn) / n \quad (1)$$

   Where :
   X = Irrigation Variable (area/Ha)
   n = Amount of Data
2. Sort the 10 daily average debit data obtained from the largest to the smallest.
3. Calculating the 80% probability of discharge from the existing 10-year debit data with the Weibull equation:

$$P = \frac{m}{n+1} \quad (2)$$

   Where :
   P = Chance (%)
   m = Data Sequence Number
   n = Amount of Data

3.4 Effective Rainfall

Effective rainfall is rainfall that falls in an area and is used by plants for its growth. Determination of effective rainfall is based on each semi-monthly, which is 70% of rain with an 80% chance of being fulfilled or a 20% chance of failing [7]. When expressed by the formula is as follows:

$$m = R_{80} \times (n + 1) \quad (3)$$

With :
R80 = Rainfall of 80%
n = Number of Data
m = Preferred Rainfall Ranking

Effective rainfall for paddy is 70% of the mid-monthly rainfall which exceeds 80% of the time period. For effective rainfall for crops is determined by the monthly period (50% fulfilled) associated with the monthly average crop ET table and monthly average rainfall [10].

For Paddy :

$$R_e \text{ paddy} = (R_{80} \times 0{,}7) \quad (4)$$

For Polowijo :

$$R_e \text{ polowijo} = (R_{50} \times 0{,}7) \quad (5)$$

With :
Re = Effective rainfall (mm/day)
R80 = Precipitation with a probability of 80%

3.5 Evapotranspiration

Evapotranspiration is the loss of water to vapor from the soil surface and water around plants (evaporation) plus evaporation from plants (transpiration) [6].

The factors that affect evaporation and evapotranspiration are water temperature, air temperature (atmosphere), humidity, wind speed, air pressure, sunlight, and others related to one another [8].

Estimates of evapotranspiration values based on climatological data always assume that the available water is in sufficient quantity to be evaporated so that the results obtained are potential evapotranspiration [5].

In this study, the calculation of potential evapotranspiration uses the Penman method in Soemarto and Michael. The Penman formula requires more measurable data, namely [11]:

1. t, average monthly temperature (C)
2. RH, average monthly relative humidity (%)
3. n/N, monthly solar brightness (%)
4. u, average monthly wind speed (m/s)

The use of more measurable data makes the calculation results of this formula more precise when compared to other formulas. What's more, H.L. Penmann developed this formula not solely based on the results of empirical experiments but also used the solar radiation energy balance concept approach [4].

3.6 Consumptive Use

Consumptive use is the amount of water used by plants for the photosynthesis process of the plant. Consumptive use is calculated by the following formula:

$$E_{tc} = K_c \cdot E_{to} \quad (6)$$

Where :
Etc = plant evapotranspiration (mm/day)
Eto = reference plant evapotranspiration (mm/day)
Kc = Crop coefficient

3.7 Percolation

Soemarto describes percolation as the downward movement of water from the unsaturated zone into the water-saturated area. The rate of percolation is highly dependent on soil properties [12]. Based on the nature of the soil, the value of the percolation rate can be seen in Table 1

Table 1. Percolation Value

No	Type Of Soil	Percolation Value (mm/day)
1	Clay Soil	1,0 - 2,0
2	Sandy Loam Soil	2,0 - 3,0
3	Sandy Soil	3,0 - 6,0

Source: Director General of Irrigation,
Program Development PSA 010, 1985

Vol. 4, No. 1, pp. 37-46, March 2023
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3.8 Water Needs During Land Preparation

For the calculation of irrigation requirements during land preparation, the method developed by Van de Goor and Zijlstra was used. The method is based on a constant water rate in It/s during the land preparation period and produces the following formula [16]:

$$LP = Me^k / (e^k - 1) \quad (7)$$

Where :
LP = Need for irrigation water at the rice field level (mm/day)
M = Water requirement to replace water loss due to evaporation and percolation in saturated rice fields

$$M = Eo + P \quad (8)$$

Where :
Eo = Evaporation of open water taken 1.1 Eto during land preparation (mm/day)
P = Percolation
k = MT/S
T = Land preparation period (days)
S = Water requirement, for saturation, add a 50 mm layer of water, namely 200 + 50 = 250 mm as explained above.
e = exponential number: 2.71828

3.9 Irrigation Water Needs

According to Sidhartha, the need for irrigation water is the volume of water needed to meet evapotranspiration needs, water loss, and water needs for plants by taking into account the amount of water provided by nature through rain and the contribution of groundwater [2]. The need for irrigation water is influenced by several factors:

1. The need for land preparation
2. Consumptive water needs for plants
3. Percolation
4. Efficiency of irrigation water
5. Area of irrigation
6. Rainfall is effective

The equation for calculating the need for irrigation water in paddy fields is as follows:

a. The net need for water in paddy fields for rice is:

$$NFR = ET_c + P + WLR - Re \quad (9)$$

Where :
NFR = Net Field Water Requirement, net water requirement in paddy fields (mm/day)
ETc = Consumptive use (mm)
LP = Water requirement for land preparation (mm)
P = Percolation (mm/ day)
WLR = Replacement of water layer (mm/day)
Re = Effective rainfall (mm/day)

b. The need for irrigation water for rice is:

$$IR = NFR/e \quad (10)$$

Where :
IR = Irrigation water requirement (mm/hr)
e = overall irrigation efficiency

c. The need for irrigation water for crops

$$IR = (ETc - Re) / e \quad (11)$$

d. The need for taking water at the source

$$DR = IR/8{,}64 \quad (12)$$

Where :
DR = Need for water withdrawal at the source (lt/s/ha)

1/8.64 = unit conversion rate from mm/day to lt/s/ha

Refer to the supporting section for Irrigation Planning Standards, Dep. P.U. the overall irrigation efficiency is 65% [4].

3.10 Linear Program

Linear programming is an irrigation planning technique that is analytical in nature whose analyses use a mathematical model with the aim of obtaining several combinations of alternative solutions to problems. The emphasis is on optimal allocation which is considered from all aspects of profit and loss in a good, balanced, and harmonious manner. It means efficient (efficient) and effective (effective) [15].

The optimal allocation is none other than maximizing the objective function that meets the requirements desired by the constraints in the form of inequalities.

The equation of the analysis in the decision-making process using linear programming basically has three stages, namely [13]:

1. Problem Identification.
2. Modeling
3. Analysis of models/calculations.

This function has the objective of optimizing irrigation. The general equation is as follows:

$$\text{Maks } Z = \sum_{i=1}^{m} (H.X) \tag{13}$$

With :

m = Number of constraints

i=1= Within 1 year

H = Unit price of irrigation converted in area

X = Irrigation target variable (irrigated area/Ha)

Limited resources which are a function of constraints in the form of available water volume and planted area.

a. Volume Constraint

$$\text{Channel Volume} = 11{,}813 \cdot 10^6 \ m^3 \tag{14}$$

b. Planted land area constraints

- A paddy + A polowijo + A tobacco
- A paddy ≤ (50% . 2754)
- A polowijo ≤ (35% . 2754)
- A tobacco ≤ (15% . 2754)

The objective function in this linear program reflects or describes the goals to be achieved in solving a linear programming problem.

3.11 Linear Program Completion

Solving the optimization problem with linear programming begins with determining the decision variables whose optimum value is to be found, which is then formed by the objective function. Then identified the constraints faced and expressed functionally, in the form of similarities or inequalities. After the modeling is complete, calculations are carried out to achieve optimum conditions [14].

Solving a linear program that has a number of decision variables less than or equal to two (n ≤ 2) can be used graphically. Whereas for equations that have more than two decision variables (n > 2), then the solution must use a mathematical/analytical method.

For most of the problems that exist, especially in the field of water resources, there are usually quite a lot of decision variables, and the right way to solve them is by mathematical/analytical method. Currently there are many computer application programs developed based on the simplex method that can be used to solve linear programming problems. This study uses existing software,

Vol. 4, No. 1, pp. 37-46, March 2023
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namely the Solver facility in Microsoft Excel to solve linear programming problems in accordance with existing problems in the field.

3.12 Solver on Microsoft Excel

Solver is a facility in the Microsoft Excel program on Windows that can be used to solve optimization problems. Solver can also be used to find a solution for the maximum or minimum value of a problem we face [9].

Solver uses non-linear optimization code developed by Leon Lasdon from the University of Texas at Austin, and Allan Waren from Cleveland State University. Problem-solving in Solver uses the simplex algorithm method with restrictions on the variables [9].

Solver is a solution search facility in Microsoft Excel software. Solver was developed based on the simplex method. If in the Microsoft Excel Pulldown menu there is no Solver facility, then the Solver facility can be installed via Add-Ins in Microsoft Excel. In calculating with Solver, three things must be fulfilled, namely:

1. Targets to be achieved.
2. Constraints that must be met
3. The contents of the cells are changed according to the terms of the value so that the targets and constraints are met.

The first step that must be given is the guessed value of the changing cell. The solver will carry out a trial and error process based on the guessed value given until a solution that meets the target and constraints is obtained. The calculation process in Solver is:

1. Determine the value of the target/goal.
2. Determine the constraint value.
3. Enter the Excel program.
4. Create worksheets in Microsoft Excel.
5. Choose a range.
6. Giving the command insert, name, and create the create names dialog box is displayed.
7. Mark the left column check box.
8. Choose OK.
9. Values X1, X2, ...Xn is given trial pressure values.
10. Write down the objectives and constraints formulas.
11. Give the command tools and solver. A dialogue box will appear.
12. Fill in the target range.
13. Select the text box by changing the cell, and enter the range to be changed.
14. Enter the constraint value, by selecting add, a dialog box will appear, and end with OK.
15. Choose Solver (point to enter).
16. After doing the calculation for a while, Excel will display a dialog box. Solver Result which notifies that a solution has been found.
17. Choose OK, done. (values in X1, X2, and goal value will change which is the value of the solution).

4. Conclusions

Based on the results of data analysis and discussion, it can be concluded the following matters:

1. From the results of the calculation of the linear program using the Solver and Microsoft Excel tools, it can be seen that the maximum land can be planted with the available discharge (inflow) at the intake. The area of land that can be planted is as follows:

Table 2. Results Of Analysis Of Optimization Studies With The Solver Program

Year	Variable	Area
Period I		
Paddy I	X1	2086,46
Tobacco II	X2	667,54
Period II		**2754,00**
Paddy I	X3	667,54
Tobacco I	X4	1391,00
Polowijo I	X5	567,35
Paddy II	X6	128,11
Period III		**2754,00**
Polowijo I	X7	323,65
Paddy II	X8	343,89
Tobacco II	X9	1261,46
Polowijo I	X10	825,00
		2754,00

Source: Calculation Results

2. Calculation of the Linear Program Method using the Solver tool from Microsoft Excel provides an analysis of the maximum profit for agricultural products of Rp. 178,183,800,000.00,-

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