The Optimization of Crop Pattern for Maximizing The Irrigation Yield in Jatikulon Mojokerto

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Abstract. There were problems to meet water demand in 431-hectare Jatikulon irrigation area in Mojokerto District from Brantas river. The purpose of this study was to obtain maximum irrigation yield in limited field under the dependable discharge constraint by Linear Programming. The variables are area of paddy, corn, and sugarcane. The constraints are dependable discharge and available irrigation area. The objective is to maximize irrigation yields. The optimization analysis reveals that the largest dependable discharge is 712 l/sec. The highest water demand for paddy, corn, and sugarcane are 2.487, 1.180, and 1.282 l/sec/ha respectively. The designed crop plants are 62 ha paddy, 369ha corn, and 0 sugarcane in season I; 0 paddy, 356ha corn and 0 sugarcane in season II; and 0 paddies, 194ha corn, and 0 sugarcane in season III. The maximum profit in season I, II, and III are Rp.6,730,554,448, Rp 5,118,677,651, and Rp.2,790,580,427 respectively.

Keywords: *dependable, discharge, crop pattern, maximum profit.*

2 1 Introduction

Population growth is directly proportional to the increasing need for life. In order to meet increasing food needs, agricultural products must be increased by farmers. Agriculture is often associated with the presence of water, because the water needs of the land that are fulfilled also affect the growth of plants, and crop yields. then it is appropriate if every land there is an irrigation system that is useful for channeling plant water needs. The availability of irrigation water must be used effectively and efficiently so that more benefits can be taken. There is a need to regulate cropping patterns in irrigation areas so that the water needs of plants can be in accordance with availability.

The Jatikulon Irrigation Area in Mojokerto with an area of 431 hectares of water extracted from the Brantas River. The Jatikulon irrigation area has delayed irrigation water to meet the water needs of plants. From the three planting seasons in a year, it is known that farmers' land was not planted in the third period because of the availability of irrigation water that was not sufficient. This was found in the rice fields of the twin villages of Kweden, Kwatu, and Leminggir. This condition causes low agricultural yields[1].

The existence of these problems, it is necessary to optimize crop pattern, so that agricultural products increase and become maximal. Plants that are commonly planted by farmers in Mojokerto include paddy, corn, sugarcane. The results of the optimization are planned for optimum cropping patterns and in accordance with the availability of irrigation water.

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Based on the background and problems mentioned above, the objectives of this discussion include: Calculate dependable discharge available in the Jatikulon Irrigation, calculating the water demand of each plant, determine the pattern of planting systems based on the availability of irrigation water, calculating the maximum profit from agricultural products.

2 Literature Review

2.1 Irrigation

Irrigation is channeling water that is necessary for the growth of the soil plants that are processed and distributed systematically[2]. In order for irrigation water to be used effectively and efficiently, it is necessary to regulate cropping patterns. The cropping pattern is a way of regulating cropland use and plant species within a certain period of time. The purpose of setting a cropping pattern is to get the amount of irrigation water for plants on the land according to availability[3].

2.2 Dependable Discharge

Dependable discharge is the minimum flow of the river for prescribed fulfilled possibilities that can be used for irrigation. The probability of being fulfilled is set at 80% (the possibility that the river discharge is lower than the mainstay discharge is 20%). River minimum discharge is analyzed on the basis of the river's daily debit data[4]. Calculation of the dependable discharge with the Basic Year Method, using equation (1)

$$R_{80} = \frac{n}{5} + 1 \quad (1)$$

Information :

n = number of observation periods (years)

R_{80} =the mainstay value with the possibility of being smaller than R_{80} has a probability of 20%, while the one greater or equal to R_{80} has a probability of 80%.

2.3 irrigation water Demand

Irrigation water demand is the amount of water volume needed to meet the needs of evapotranspiration, water loss, water requirements for plants by noting the amount of water supplied by nature through rain and groundwater contributions[5]. The planned discharge rate is influenced by Net field requirements, irrigated area, and channel irrigation efficiency.Irrigation water demand is calculated using equation (2)

$$\text{water demand per hectare} = \frac{NFR \times A}{e} \quad (2)$$

Information :

NFR =net field requirements (mm/day)

A =area irrigated (ha)

e =irrigation efficiency

Efficiency in each plot is estimated as follows[4]

a. Water losses in tertiary channels are 15 - 22%. The amount of irrigation efficiency ranges from 77.5% - 85%
b. The water loss in the secondary channel is 7.5 - 12.5%. The amount of irrigation efficiency ranges from 87.5% - 92.5%

c. Water losses in the primary channel are 7.5 - 12.5%. The amount of irrigation efficiency ranges from 87.5% - 92.5%

Calculationnet field requirements using equation (3)and equation (4)

$$NFR_{paddy} = Cu + Pd + P + WLR - Re \quad (3)$$

$$NFR_{crops} = Cu - Re \quad (4)$$

Information :

Cu = plant water requirements (mm/day)

P =water loss due to percolation (mm/day)

Pd =land preparation needs (mm/day)

Re = effective rainfall (mm/day)

WLR = replacement of standing water (mm/day)

2.4 Crop Pattern Optimization

Optimization is an attempt to determine the best solution from a number of alternatives with various constraints that exist on a model[6]. The analysis in this study uses linear programs because the use of linear programs has the following advantages:

a. This method can be used to complete the system by changing the constraint function sufficiently
b. This use is easy and accurate
c. The mathematical function is simple

Meanwhile, the limitations of this program are that they cannot analyze complex irrigation area systems. So it needs to be simplified in analyzing irrigation area system. Completion of optimization problems with linear programs begins by determining the decision variable that the optimum value wants to find. This mathematical model consists of two parts, namely:

1) Purpose Function

The purpose function is to maximize profits from land use with available water. Equation (5) for the following:

$$Z = C1X1 + C2X2 + \ldots + CnXn \quad (5)$$

Information :

Z = purpose function (maximum profit of agricultural produce) (Rp.)

Cn = net profit (Rp./ha)

Xn= area of irrigation (ha)

2) ConstraintsFunction

The constraint function is the equation of the amount of plant water needs which is limited by the availability of each planting period and area of each plant which is limited by total area. Equation (6), equation (7) and equation (8) for the following:

$$a11X1 + a21X2 + \ldots + anmXn \leq bm \quad (6)$$

$$X1 + X2 + \ldots + Xn \leq \Sigma X \quad (7)$$

$$X \geq 0 \quad (8)$$

Information :

X= area of irrigation (ha)

a = irrigation water demand (l/sec/ha)

b = dependable discharge (l/sec)

n = number of decision variables

m = number of constraints

3 Method

This method will be used as a reference in carrying out the stages of research so that the time provided can be utilized as optimally as possible[6].

a. Collect data. These data include intake discharge secondary channel, rainfall from Tampung, Sambiroto and Terusan stations of in 2008-2017, type of soil, climatology from KP Mojosari station in 2013-2017, profit analysis per hectare[7].
b. Conduct a literature study. The study was carried out both through irrigation books, planning criteria, and scientific journals.
c. Calculating dependable discharge. In the calculation using Jatikulon intake discharge.
d. Calculate the effective rainfall from rainfall data. And process climatology data into potential evapotranspiration data. by calculating plant coefficients and potential evapotranspiration that produce value for plant water needs.
e. Calculate water requirements for land preparation, change of water layer, and percolation.
f. Calculating the net field requirements that are influenced by effective rainfall, percolation, crop water requirements, cropping patterns and associated with irrigation efficiency data in the field then calculate the water demand per hectare.
g. Create a mathematical model of the water demand, Dependable Discharge, and the purpose of finding the maximum profit gained from each hectare of the plant to be planted.
h. Optimization using linear programs, and controls, if not ok back to planting plans and water demand per hectare.
i. The optimal cropping pattern is obtained, then find out what the maximum profit value is. and finished.

The sequence of research stages is illustrated in the following flow chart:

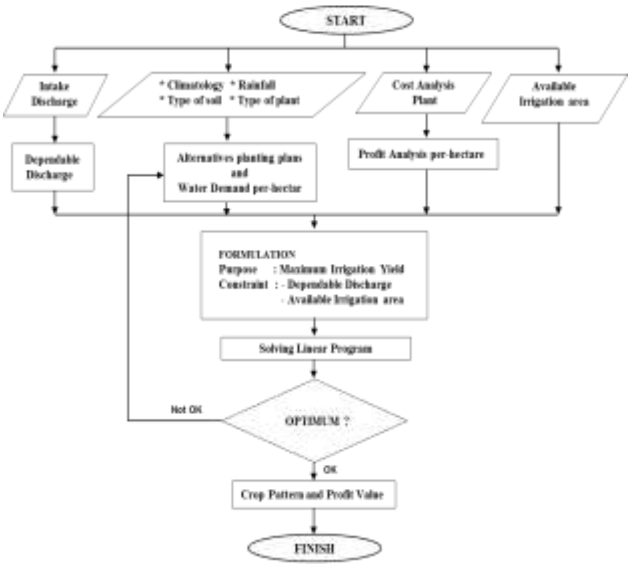

Figure 1. Research Completion Flow Chart

4 Result and Discussion

Dependable Discharge

Calculation results dependable discharge using equation (1)

November			**December**			**January**			**February**		
I	II	III	I	II	III	I	II	III	I	II	III
183	216	463	342	712	673	664	472	617	447	518	545
March			**April**			**May**			**June**		
I	II	III	I	II	III	I	II	III	I	II	III
360	554	481	349	328	315	234	334	436	429	402	455
July			**August**			**September**			**October**		
I	II	III	I	II	III	I	II	III	I	II	III
459	364	303	352	323	330	267	240	186	175	163	158

Table 1. Dependable Discharge (l/sec)

Irrigation Water Demand

The planned discharge rate is influenced by net field requirements, irrigated area, and channel irrigation efficiency.[8]Calculation results of irrigation water demand using equation (2)

Month	**Period**	**Water Demand (l/sec/ha)**		
		Paddy	**Corn**	**Sugarcane**
November	I	2.487	0.067	0.123
	II	2.233	0.209	0.317
	III	1.772	0.250	0.332
December	I	1.543	0.423	0.420
	II	1.110	0.148	0.077
	III	1.596	0.497	0.427
January	I	1.482	0.471	0.410
	II	1.259	0.377	0.424
	III	0.494	0	0.101
February	I	0.497	0	0.362
	II	0.882	0	0.476
	III	1.270	0	0.489

Table2. Water Demanding Season I

Month	Period	Water Demand (l/sec/ha)		
		Paddy	Corn	Sugarcane
March	I	1.139	0	0.286
	II	1.489	0	0.702
	III	1.243	0.008	0.669
April	I	1.383	0.342	0.727
	II	1.586	0.509	0.758
	III	1.560	0.485	0.656
May	I	1.722	0.658	0.791
	II	1.556	0.605	0.794
	III	1.466	0.590	0.863
June	I	1.221	0.278	0.795
	II	1.515	0.114	0.795
	III	1.872	0	0.795

Table 3. Water Demand in Season II

Month	Period	Water Demand (l/sec/ha)		
		Paddy	Corn	Sugarcane
July	I	0	0.046	0.972
	II	0	0.180	0.972
	III	0	0.368	0.972
August	I	0	0.692	1.141
	II	0	0.851	1.141
	III	0	0.942	1.141
September	I	0	1.180	1.282
	II	0	1.092	1.171
	III	0	0.959	1.061
October	I	0.444	0.541	0.902
	II	1.331	0.221	0.517
	III	2.219	0	0.148

Table 4. Water Demand in Season III

Crop Pattern Optimization

The analysis in this study uses a linear program and steps taken first are interpreting the problems in the study area. 431-hectare Jatikulon irrigation area in Mojokerto. Based on the analysis of harvest profit, it is obtained from several sources with some adjustments to the unit price of Mojokerto area approved by agriculture service having following values: net profit of paddy per hectare per season Rp.22,895,000 and corn per hectare per season Rp.14,390,000. each planting season lasts approximately four months so that in one year there are three planting periods.While net profit of sugarcane per hectare per season or one year Rp.

38,332,000. In order to get the same profit value every four months, the profit of sugar cane per hectare per season is divided by three so that the value of profit is Rp.12,777,333[2].

The purpose is to maximize irrigation yields. The decision variables specified are:

X1 =the area planted with paddy (ha)
X2 =the area planted with corn (ha)
X3 =the area planted with sugarcane (ha)

The constraints:

Alternative I : constraints are dependable discharge and available irrigation area.

Alternative II : constraints are dependable discharge and available irrigation area + existing sugarcane (55ha).

Alternative III : constraints are dependable dischargeand available irrigation area + increase supply sugarcane (110ha).

Formation of linear program formulations is made every planting season, according to the purpose and constraints of each season[1].

1. Formulation of linear program season I

Purpose function : Maximize Z = 22,895,000 X1 + 14,390,000 X2 + 12,777,333 X3

Constraint function:

2.487	X1	+	0.067	X2	+	0.123	X3	≤	183
2.233	X1	+	0.209	X2	+	0.317	X3	≤	216
1.772	X1	+	0.250	X2	+	0.332	X3	≤	463
1.543	X1	+	0.423	X2	+	0.42	X3	≤	342
1.110	X1	+	0.148	X2	+	0.077	X3	≤	712
1.596	X1	+	0.497	X2	+	0.427	X3	≤	673
1.482	X1	+	0.471	X2	+	0.41	X3	≤	664
1.259	X1	+	0.377	X2	+	0.424	X3	≤	472
0.494	X1	+	0	X2	+	0.101	X3	≤	617
0.497	X1	+	0	X2	+	0.362	X3	≤	447
0.882	X1	+	0	X2	+	0.476	X3	≤	518
1.270	X1	+	0	X2	+	0.489	X3	≤	545
X1		+	X2		+	X3		≤	431
(addition of constraints alternative II)						X3		=	55
(addition of constraints alternative III)						X3		=	110

X1 = 62ha, X2 = 369ha, X3 = 0ha, optimum results alternative I, Rp.6,730,554,448maximum profitalternative I.

X1 = 59ha, X2 = 317ha, X3 = 55ha, optimum results alternative II, Rp.6,617,023,693maximum profitalternative II.

X1= 56ha, X2= 265ha, X3= 110ha, optimum results alternativeIII, Rp.6,503,492,938maximum profitalternative III.

2. Formulation of linear program season II

Purpose function : Maximize Z = 22,895,000 X1 + 14,390,000 X2 + 12,777,333 X3

Constraint function :

1.139	X1	+	0	X2	+	0.286	X3	≤	360
1.489	X1	+	0	X2	+	0.702	X3	≤	554

1.243	X1	+	0.008	X2	+	0.669	X3	≤	481
1.383	X1	+	0.342	X2	+	0.727	X3	≤	349
1.586	X1	+	0.509	X2	+	0.758	X3	≤	328
1.560	X1	+	0.485	X2	+	0.656	X3	≤	315
1.722	X1	+	0.658	X2	+	0.791	X3	≤	234
1.556	X1	+	0.605	X2	+	0.794	X3	≤	334
1.466	X1	+	0.590	X2	+	0.863	X3	≤	436
1.221	X1	+	0.278	X2	+	0.795	X3	≤	429
1.515	X1	+	0.114	X2	+	0.795	X3	≤	402
1.872	X1	+	0	X2	+	0.795	X3	≤	455
X1		+	X2		+	X3		≤	431
(addition of constraints alternative II)						X3		=	55
(addition of constraints alternative III)						X3		=	110

X1 = 0ha, X2 = 356ha, X3 = 0ha, optimum results alternative I, Rp.5,118,677,651maximum profit alternative I.
X1 = 0ha, X2 = 290ha, X3 = 55ha, optimum results alternative II, Rp.4,869,220,762maximum profit alternative II.
X1 = 0ha, X2= 223ha, X3 = 110ha, optimum results alternative III, Rp.4,619,763,873maximum profit alternative III.

3. Formulation of linear program season III
Purpose function : Maximize Z = 22,895,000 X1 + 14,390,000 X2 + 12,777,333 X3
Constraint function :

0	X1	+	0.046	X2	+	0.972	X3	≤	459
0	X1	+	0.180	X2	+	0.972	X3	≤	364
0	X1	+	0.368	X2	+	0.972	X3	≤	303
0	X1	+	0.692	X2	+	1.141	X3	≤	352
0	X1	+	0.851	X2	+	1.141	X3	≤	323
0	X1	+	0.942	X2	+	1.141	X3	≤	330
0	X1	+	1.180	X2	+	1.282	X3	≤	267
0	X1	+	1.092	X2	+	1.171	X3	≤	240
0	X1	+	0.959	X2	+	1.061	X3	≤	186
0.444	X1	+	0.541	X2	+	0.902	X3	≤	175
1.331	X1	+	0.221	X2	+	0.517	X3	≤	163
2.219	X1	+	0	X2	+	0.148	X3	≤	158
X1		+	X2		+	X3		≤	431
(addition of constraints alternative II)						X3		=	55
(addition of constraints alternative III)						X3		=	110

X1 = 0ha, X2 = 194ha, X3 = 0ha, optimum results alternative I, Rp.2,790,580,427maximum profit alternative I.
X1= 0ha, X2 = 133ha, X3 = 55ha, optimum results alternative II, Rp.2,617,997,354maximum profit alternative II.
X1= 0ha, X2 = 72ha, X3= 110ha, optimum results alternative III, Rp.2,445,414,282maximum profit alternative III.

Results from the analysis and calculation of the three alternatives, the greatest benefit value if applying alternative I. The designed crop plants is 62ha paddy, 369ha corn, and 0 sugarcane in season I; 0 paddy, 356ha corn and 0 sugarcane in season II; and 0 paddy, 194ha corn and 0 sugarcane in season III.Rp.6,730,554,448 maximum profit in season I, Rp.5,118,677,651 maximum profit in season II, Rp.2,790,580,427 maximum profit in season III.

5 Conclusion

Based on the results of analysis and calculations

a. The largest dependable discharge is 712 l/sec in December.
b. The highest water demand for paddy, corn, and sugarcane are 2.487, 1.180, and 1.282 l/sec/ha respectively.
c. The designed crop plants are 62 ha paddy, 369ha corn, and 0 sugarcane in season I; 0 paddy, 356ha corn and 0 sugarcane in season II; and 0 paddies, 194ha corn, and 0 sugarcane in season III.

The maximum profit in season I, II, and III are Rp.6,730,554,448, Rp 5,118,677,651, and Rp.2,790,580,427 respectively. The story spread around the island in Indonesia, giving another conclusion, could be the story represent man's behavior toward a woman in order to attract a woman's heart.Robi in Wibowo [9]found that it is possible JakaTarub's Story and Tanaba have the same characters, plot and setting even though Indonesia and Japan located in the far distance. According to Lévi-Strauss [9], the similarity of the story (in Indonesia and Japan), is

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