Analysis of Water Availability and Demand in The Kromong II Dam Irrigation Mojokerto Regency

Nanda Galuh Kameswara[1], Danayanti Azmi Dewi Nusantara[2]
[1,2]Department of Civil Engineering, Universitas Negeri Surabaya
Ketintang Street, Ketintang, Gayungan, Surabaya, East Java 60231
E-mail: nanda.21108@mhs.unesa.ac.id

Abstract* — East Java Province has authority over the irrigation area of Mojokerto Regency, one of which is the Irrigation Area of Kromong II which has an area of 1,055 Ha. Kromong Dam is located in the Kromong River, Sajen Village, Mojokerto Regency. The main problem in the Kromong II Irrigation Area is the lack of irrigation water available with the water needs of the rice fields during the dry season, and this was caused by changes in farmers' cropping patterns that exceed planning. Because of this, it is necessary to optimize profits with the land area that best suits the type of plant and water availability. Calculation of water availability uses the F.J Mock method by including rainfall and potential evapotranspiration data. This calculation is followed by an analysis of plant water needs which are adjusted to the planned planting pattern. The analysis in this research used a linear program assisted by QM for Windows 5. From the optimization results after adding water from four pump wells with a capacity of 20 lt/sec, a planting intensity of 200% was obtained in the paddy-paddy-crop planting pattern, with profits obtained greater than the existing amount of Rp 43.176.461.200,-.
***Keywords:* irrigation area; irrigartion; planting patterns; linear program; optimization.**

I. INTRODUCTION

Indonesia as an agricultural country has abundant natural resources which are used as a source of income and food (Setiadi et al., 2018). Indonesia is projected by the Organization for Economic Cooperation and Development (OECD) to be the 5th ranked country in GDP (Gross Domestic Product) in the world in 2045 which commits to safeguarding resources so that GDP can be maximized. The government has set several targets related to sustainable water resources management by 2024, including 100% of housing with access to adequate drinking water, 30% of housing with access to piped drinking water, increasing the capacity of national water resources by around 2,3 billion m^3, and supply sustainable irrigation water from reservoirs of around 355,8 thousand hectares. Water resource management is necessary considering the vital need for water, especially to meet the sustainability demand of plants or agricultural land.

The government fulfills water needs, one of which is by establishing an irrigation system so that crop water needs can be fulfilled every season. This is by Government Regulation (PP) no. 20 of 2006 concerning irrigation, which mandates that the development and management of irrigation needs to be carried out by farmers and the government. Irrigation is the business of providing and regulating water to meet agricultural needs and can be used for other purposes such as raw water, drinking water supply, electricity generation, industrial purposes, fisheries, or flushing water (Laksitaningtyas, 2016). Optimal use of irrigation water needs to be done by streamlining the distribution and use of available irrigation water so that existing agricultural land can be irrigated optimally (Saputra F, 2018).Water demand also need to be considered and adjusted to water availability in managing irrigation systems, especially in rice fields which rely heavily on water availability from rivers and rain.

According to the PUPR Ministerial Decree no. 14/PRT/M/2015, which outlines the criteria and determination of irrigation area status, there are 8.913 irrigation areas in East Java. The Water Resources Public Works Department of East Java Province has jurisdiction over 7 irrigation areas in Mojokerto Regency, including Irrigation Area Kromong II, which spans an area of 1.055 hectares. Kromong II Dam is located in Sajen Village, Pacet District, Mojokerto Regency, Kromong II Dam is located on the Kromong River that has the main function of meeting irrigation needs and is used for areas around the river. The main problem in the Kromong II Irrigation Area is the lack of available water flow with current water needs in the dry season and is due to changes in farmers' cropping patterns. The final planned planting pattern was paddy-paddy-crop, but in reality, most farmers planted more paddy than planned. This is in line with the opinion (Saputra F, 2018) that the problem often faced by farmers is a lack of water, especially in the dry season, which causes problems such as reduced crop yields, vulnerability to pest attacks, and competition for water for agricultural land.

Meeting the increasing need for irrigation as a solution to existing problems in Pacet District, especially the Kromong II Bendung Irrigation Area, does not allow for the opening of new land. Increases are carried out in the right way for agricultural products, by using good water distribution methods so that existing water demand will be adjusted to water availability. Optimizing more optimal planting patterns can also be another solution that can be implemented in order to produce maximum profits with optimal land area (Risfiyanto et al., 2017). Alternatives for optimizing planting patterns to maximize water in this research are obtained from surface water and ground water sourced from pump wells as a step to fulfill water needs according to the planting pattern to be used.

Research on water availability by optimizing planting patterns using the Quantity Methods for Windows program was carried out by Ferdiansyah et al., (2023) to obtain the results of an analysis of calculations of existing water needs, planned planting patterns and agricultural production results. Another research conducted by Noerhayati et al., (2017) produced 3 alternative planned planting patterns, and obtained maximum profits. Subsequent research from Saves et al., (2022) produced the results of an analysis of alternative planting patterns to obtain the effectiveness of irrigation water requirements (NFR) and the maximum profit value. The differences between previous research and this research lie in the research area, age data and data sources used, as well as the linear programming application used.

Based on the background of the problem above, the researcher entitled this research "Analysis of Water Availability and Demand in the Kromong II Dam Irrigation Canal" which can help analyze water availability and demand as well as optimize the results of appropriate planting patterns in the Kromong II Dam Irrigation Area.

II. LITERATURE REVIEW

Irrigation

Based on UU no. 7 of 2004 in article 41 section 1 concerning Water Resources, irrigation is the business of providing, regulating and disposing of water which aims to support agriculture, including surface irrigation, swamp irrigation, underground water irrigation, pump irrigation and pond irrigation. UU No. 7 of 2004 states that irrigation includes efforts to provide, regulate and dispose of water with the aim of supporting agriculture.

Water Discharge

Water discharge is the quantity of water that flows from a source per unit of time, typically measured in liters per second. The amount of liquid that flows through the flow cross-section per unit of time is called the flow discharge (Q). The discharge formulation can be seen using formula below:

$$Q = A \times v \qquad \dots 1)$$

Annotation:
Q = Flow (m^3/sec);
A = Cross-sectional area (m^2);
V = Flow speed (m/sec).

Effective Rainfall

Effective or reliable rainfall is the part of the total rainfall that is effectively available for plant water needs (KP – 01, 2013). For paddy irrigation purposes, effective rainfall (Re) is planned
70% of the mid-monthly average rainfall with a 20% probability of non-fulfillment (R80). Meanwhile, for the needs of crops, the probability of being met is 50% (KP – 01, 2013).

$$R_e\, paddy = 0{,}7x\left(\frac{1}{15}\right)R_{80}\ (\,setengah\ bulan\,) \qquad \dots 2)$$

$R_e\text{crop} = 0{,}80\, xR_{50} - 25/30$
If R_{50} > 75 mm/month
$Re\text{ crop} = 0{,}60\, xR(50) - 10/30$
If R_{50} < 75 mm/month

Annotation:
R_e = Effective Rainfall (mm/day)
R_{80} = The 10 daily rainfall is exceeded 80% of the time (m^2)

Average Rainfall

Rainfall is very necessary for a design water utilization is good for determining water demand necessary or for flood control purposes (Mushthofa et al, 2022). There are three methods to analyze average rainfall: the arithmetic mean method, the Thiessen polygon method, and the isohyet method (Triatmodjo, 2010). The study use the arithmetic mean method. The arithmetic mean method can be formulated below:

$$\acute{P} = \frac{P_1+P_2+P_3+...+P_n}{n} \quad ... 3)$$

Annotation :

$\acute{P}$ = Regional average rainfall

$P_1, P_2, ... P_n$ = Raining at the station 1,2, ..., n

N = Number of stations

Water Availability

Water availability in terms of water resources comes from rainwater (atmospheric), surface water, and groundwater (Pola et al., 2016). Empirical formula calculations are adjusted to data availability, in this calculation using the F.J. Mock method to get reliable discharge and calculate water availability. F.J Mock method calculations are based on monthly rainfall data, number of rainy days, evapotranspiration and hydrological characteristics of the drainage area (Syahputra et al., 2015). Water availability which is part of a natural phenomenon, is often difficult to regulate and predict accurately. This is because water availability contains elements of spatial variability and temporal variability (temporal variability) is very high (Sitompul & Efrida, 2018).

Irrigation water needs

The need for water for agricultural land irrigation networks can be divided into several parts, namely the need for clean water on agricultural land, the need for irrigation water for rice and/or crop, and the need for water extraction from the source.The clean water requirement in rice fields for rice is in formula below:

a. Clean water requirements in rice fields for paddy are in formula below:

$$\text{NFR} = \text{ETc} + \text{P} + \text{WLR} - \text{Re} \quad ... 4)$$

Annotation:

NFR = *Netto Field Water Requirement*, Water needs in rice fields (mm/day);

ETc = Evapotranspirasi tanaman (mm/day)

P = Perkolasi (mm/day);

WLR = Water layer requirements (mm/day);

Re = Efektif rainfall (mm/hr).

b. water requirements for paddy are in formula below:

$$\text{IR} = \frac{NFR}{e} \quad ... 5)$$

Annotation:

IR = Irrigation water requirement (mm/day)

e = Overall irrigation efficiency

c. Irrigation water requirements for crop are in formula below:

$$\text{IR} = \frac{ET_c - \text{Re}}{e} \quad ... 6)$$

d. The source water requirement is in the formula below:

$$\text{DR} = \frac{IR}{8{,}64} \quad ... 7)$$

Annotation :

DR = water requirements at the source (mm/day);

e = overall irrigation efficiency;

$\frac{1}{8{,}64}$ = unit conversion number from mm/day to lt/dt/ha.

Evapotranspiration

Planning and implementing a water management system to estimate evapotranspiration is an important step because water loss on the surface of soil or plants has a direct effect on the amount of water available. In this research, the method used is a method produced based on a combination of aerodynamics and energy balance using Alfa grass as a reference plant. Calculation of the Modified Penman method to determine the value of potential evapotranspiration (ETo) as in formula below:

$$ETo = c.(\text{W.Rn} + (1 - \text{W}).\text{f(U)}.(\text{es} - \text{ea})) \quad ... 8)$$

Annotation:

ETo = Daily potential evapotranspiration in (mm/day);

c = Adjustment factor for day and night weather conditions;

W = Factors that influence solar radiation;

F(U) = Wind speed function in comparison;

C = Adjustment factor for conditions due to day and night weather;

Rn = Solar radiation in comparison;

ea = Actual vapor pressure (mbar);

es = Saturation vapor pressure (mbar).

Planting Pattern

Determining planting patterns to fulfill water demand is something that require to be considered (PriyoNugroho, 2014).

Table 1. Planting pattern

Availability of water for irrigation network	One year planting pattern
	Paddy-paddy-crop
There is plenty of water available	Paddy-paddy-bera
There is plenty of water available	Paddy-crop-crop
Areas that tend to lack water	Paddy-crop-bera crop-paddy-bera

Source: Sidharta, 1997

The planting pattern is a planned sequence of scheduled planting types of plants in an irrigated area for one year or more. Once there is a planned planting pattern, the initial determination of the crop is carried out by trying to shift the initial planting time by a period of 45 days to obtain the maximum planting area (Setiyawan et al., 2017)

Linier Program Model

The analytical method used is an optimization method using a Linear Program by considering water availability and land area for rice and secondary crops for 3 (three) alternative planting patterns in the rainy season, Dry Season I and Dry Season II with planting periods MH, MT II and MT III. The constraints in carrying out optimization analysis have objective and constraint functions. In the mathematical model of the constraint function, the total land area for each type of plant in each group does not exceed the total land area in the irrigation area (Septyana et al., 2016).

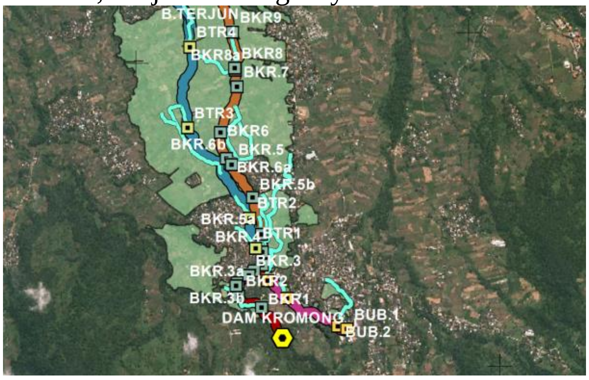
Water Balance

Water balance is the amount of flow entering and leaving a system, which can be a river area or river basin that flows water from upstream points as inlets to downstream as outlets (Sitompul & Efrida, 2018). The water balance at the intake gate for each irrigation water distribution period can be calculated using formula below:

$$NA = Q_{Tersedia} - Q_{Kebutuhan}$$

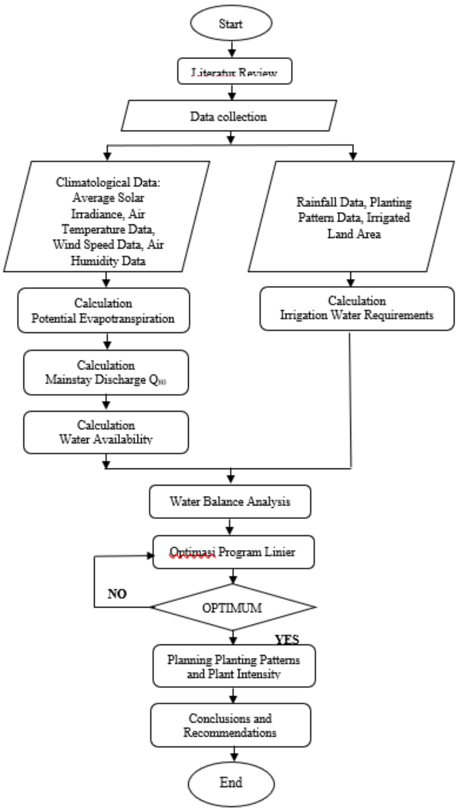
III. METHOD

This research was conducted in the Kromong II Bendung Irrigation Area, Sajen Village, Pacet District, Mojokerto Regency, East Java Province. Administratively, DI Kromong II is within the working area of the Pugeran UPT Service branch which covers 15 villages and 3 sub-districts, namely Gondang, Pacet, and Kutorejo sub-districts, Mojokerto Regency.



Picture 1. Location of Kromong II Dam

Literature studies are carried out by understanding and studying the concept of irrigation systems and then finding solutions to the irrigation conditions needed. The supporting data used was obtained from the relevant agency, namely bulk data for the last 10 years obtained from the East Java Province Water Resources Public Works Department, Data on water discharge measurements and cropping patterns for the past 10 years were obtained from UPT PU SDA Korwil Surabaya. Additionally, climatology data was obtained from BMKG Djuanda Sidoarjo Meteorological Station. The framework for this research is shown Figure 2.



Picture 2. Research flow chart

IV. RESULTS AND DISCUSSION

Climatology and Potential Evapotranspiration

Climatological calculations to determine the amount of plant evapotranspiration, these calculations include wind speed, air temperature, relative humidity and duration of sunlight. The Penman evapotranspiration method was used in this calculation, where data was obtained from the Meteorology, Climatology and Geophysics Agency, Djuanda I Meteorological Station located in Sidoarjo Regency, East Java. Examples of calculation steps can be seen in the table 2 below.

Table 2. Calculation of potential evapotranspiration (ETo) in January period I

No	Description Meteorological Data		January Periode I
1	Temperature	°C	27,94
2	Air Humidity	%	83,60
3	Wind velocity	m/sec	1,60
4	Solar Irradiation	hour	4,15
		n/N	34,58
5	Calculation Saturated Vapor Pressure	mbar	37,67
6	Influence Factors: Temperature and elevation		0,77
7	Weighting factor (1-W)		0,23
8	Temperature Function	°C	16,29
9	Actual vapor pressure	mbar	31,50
10	Vapor pressure function	mbar	0,09
11	Shortwave radiation is appropriate	mm/day	16,10
12	Short Wave Radiation	mm/day	7,03
13	Sun Brightness Function	mm/day	0,41
14	Wind Speed Function	m/sec	0,64
15	Long wave net radiation	mm/day	0,62
16	Correction figure		1,10
17	Evaporation Potential	mm/day	4,50
18	Evapotranspiration Potential	mm/day	4,95
19	Evapotranspiration	mm/10 day	49,47

Source: Calculation results (2023)

Regional Rainfall

The data on rainfall from the Irrigation Area of Kromong II is from three rain stations: Mojosari, Pacet, and Pasinan Rain Station. The data spans a period of ten years, from 2013 to 2022. Data calculations use the arithmetic method as below.

Regional rainfall in period I of January 2022

Mojosari Station = 114 mm/month

Pacet Station = 149 mm/month

Pasinan Station = 34 mm/month

$$p = \frac{P1 + P2 + P3}{n}$$

$$p = \frac{114 + 149 + 34}{3}$$

$$p = \frac{297}{3}$$

p = 99,0 mm/bulan

Water Availability

Calculation of water availability or mainstay discharge in DI Kromong using the F.J. Method. Mock can be seen in the calculation table 3 for January Period I below

Table 3. Calculation of Water Availability FJ Mock Method in 2022

No	Description Meteorological Data		January Periode I
1	Monthly Rain (R)	mm/day	99,00
2	Number of Rainy Days (n)	day	5
3	Number of Days 1 month	day	10
	Actual Evapotranspiration		
4	Potential Evapotranspiration	mm/ day	4,95
5	Exposed surface (m)	%	0,35
6	E/ET=(m/20)x(18+n)	%	0,40
7	Change in evapotranspiration (Ee)	mm/ day	1,99
8	actual evapotranspiration (Ea)	mm/ day	2,96
9	Water Balance		
10	Δs = R-Ea	mm/ day	96,04
11	SMS		296,04
12	SMC		200,00

13	SS	mm	0,00
14	Water Surplus (WS)	mm	96,04
	Groundwater Runoff and Storage		
15	I		38,42
16	1/2(1+K)I = Gsom		30,73
17	K(Vn-1)		3,49
18	Groundwater storage (GWS)		34,23
18	Vn =Vn-1 + Vn		10,05
19	BSF		28,37
20	DRO		57,63
21	TRO		85,99
22	Monthly Discharge	m^3/s	1,05

Source: Calculation results (2023)

After calculating the mainstay discharge, it is added to the base flow of 303 lt/sec (from intake discharge) to obtain the total discharge. The final discharge results are presented in the table 4 below.

Table 4. Recapitulation of FJ Mock mainstay discharge calculations 2013-2022 (m3/s)

Januari			Februari			Maret		
I	II	III	I	II	III	I	II	III
1,06	1,39	1,78	1,84	1,59	1,94	1,83	1,28	1,21
April			**May**			**June**		
1,44	1,36	1,05	0,57	0,59	0,60	0,58	0,48	0,56
July			**August**			**September**		
0,38	0,31	0,37	0,31	0,30	0,30	0,30	0,30	0,30
October			**November**			**December**		
0,30	0,30	0,30	0,31	0,35	0,83	0,79	0,89	1,10

Effective Rainfall

Effective rainfall analysis is based on 10 years of daily rainfall data, with a probability of 80% for reliable rainfall. This means there is an 80% chance of utilizing reliable rainfall for plants.

Calculation of Re for each plant using the formula:

$R_{e\ Paddy}$ = (R_{80} x 70%)/10 (mm/day)

$R_{e\ Crop}$ = (R_{80} x 50%)/10 (mm/day)

Table 5. Results of effective rainfall calculation for paddy

January			February			March		
I	II	III	I	II	III	I	II	III
5,65	7,70	2,43	1,24	7,61	6,74	7,98	4,92	4,48
April			**May**			**June**		
3,85	3,73	2,43	1,24	0,14	0,40	0,00	0,00	0,00
July			**August**			**September**		
0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
October			**November**			**December**		
0,00	0,00	0,00	0,00	0,16	2,47	4,41	4,74	5,69

Source: Calculation results (2023)

Table 6. Results of effective rainfall calculation for crop

January			February			March		
I	II	III	I	II	III	I	II	III
2,90	2,90	2,90	3,08	3,08	3,08	2,16	2,16	2,16
April			**May**			**June**		
1,41	1,41	1,41	0,25	0,25	0,25	-0,10	-0,10	-0,10
July			**August**			**September**		
-0,10	-0,10	-0,10	-0,11	-0,11	-0,11	-0,13	-0,13	-0,13
October			**November**			**December**		
-0,12	-0,12	-0,12	0,46	0,46	0,46	2,00	2,00	2,00

Source: Calculation results (2023)

Percolation

Percolation value, or water seepage that enters the soil, is very important because it affects water requirements for irrigation. The percolation value depends on soil conditions, and the percolation rate value can decrease as a result of land processing. Based on the medium clay texture, the percolation rate can be used at 2 to 3 mm/day. In this calculation, a value of 2 mm/day is taken according to existing conditions in the field.

Plant Coefficient

The crop coefficient is needed for linking potential evapotranspiration (ETo) with consumptive water requirements for plants (ETc). According to the existing global planting plan data, the types of plants in the DI Kromong area, Mojokerto Regency consist of paddy and crops (corn).

Irrigation Efficiency

The irrigation efficiency value is obtained by dividing the clean water requirements of NFR paddy fields by overall irrigation efficiency. The overall irrigation efficiency reaches 65%, which results from the multiplication of 80% in primary channels, 90% in secondary channels, and 90% in tertiary channels.

Water Layers Requirement

The height of the puddle when changing the water layer is 50 mm for 1 month (30 days).

$$WLR = \frac{50\ mm}{15\ day} = 3{,}3\ mm/day$$

Water Requirements for Land Preparation

To calculate irrigation needs for land preparation, the method developed by Van de Goor and Zijlstra (1968) was used. Irrigation water requirements at the rice field level during land preparation, calculation results in January period I:

$$IR = M . \frac{e^k}{(e^k - 1)}$$

$$IR = 8{,}02 . \frac{e^{0.83}}{(e^{0.83} - 1)}$$

$$IR = 14{,}24 \text{ mm/day}$$

Table 7. Calculation of water requirements for land preparation during the rainy season

Planting Season	Month	Period	Eto	Eo	P	M	k	IR
			mm/day	mm/day	mm/day	mm/day	mm	mm/day
1	2	3	4	5	6	7	8	9
MH	Des	I	6,04	6,65	2	8,65	0,89	14,64
		II	5,7	6,27	2	8,27	0,86	14,4
		III	5,99	6,59	2	8,59	0,89	14,6
	Jan	I	5,47	6,02	2	8,02	0,83	14,24
		II	5,71	6,28	2	8,28	0,86	14,4
		III	5,72	6,29	2	8,29	0,86	14,41
	Feb	I	5,97	6,56	2	8,56	0,8	15,56
		II	5,62	6,18	2	8,18	0,76	15,32
		III	5,95	6,54	2	8,54	0,8	15,55
	Mar	I	4,81	5,3	2	7,3	0,75	13,78
		II	4,91	5,4	2	7,4	0,76	13,85
		III	5,17	5,69	2	7,69	0,79	14,03

Source: Calculation results (2023)

Calculation of Water Requirements for Plants

To increase crop yields in irrigated areas, it is important to analyze the water needs of plants during their respective planting periods. This involves selecting the appropriate planting pattern, as each plant has a different planting period and water requirement coefficient. It is essential to choose the right planting pattern based on the availability of water, to optimize crop growth and yield. The division of months of the growing season in this optimization study is:

1. Rainy planting season (MH) = December to March;
2. Dry planting season I (MK1) = April to July;
3. Dry planting season II (MK2) = August to November.

The calculation can be seen in table 8 below. Calculate the DR Value:

$$\text{DR} = \frac{\text{NFR}}{\text{Efisiensi Irigasi}}$$

Table 8. Calculation of plant water requirements for planting pattern 2 (paddy-paddy-crop)

No	Description	January	
		Periode I	Periode II
	Planting Pattern	LP	
1	Planting Coef. c1	LP	1,1
	Planting Coef. c2	LP	LP
2	Planting Coef. c3	LP	LP
3	kc	0,00	0,37
	Eto	5,47	5,71
4	Etc	0,00	2,09
5	Land Preparation (IR)	14,24	14,24
6	Land Preparation Ratio	0,33	0,33
7	Ir x Ratio	4,70	4,70
8	Percolation (P)		
9	WLR 1		
10	WLR 2		
11	WLR 3		
12	Average WLR	0,00	0,00
13	Plant Area Ratio		
14	Etc+P+WLR	0,00	2,09
15	Re (mm/hr)	5,65	7,70
16	Total Ratio	0,33	0,33
17	Re x Total Ratio	1,86	2,54
18	NFR (mm/hr)	-1,86	-0,45
19	NFR (lt/dt/ha)	-0,22	-0,05
20	Irrigation Efficiency	0,65	0,65
21	DR (Lt/sec/ha)	0,00	0,00
22	DR (Lt/s)	0	0

Source: Calculation results (2023)

Linear Program Optimization Modeling

The area results produced by the optimization process aim to achieve the ideal area distribution so that production results can be maximized. Optimization modeling was carried out to overcome problems in utilizing irrigation water from the Kromong II Dam so that it can produce maximum production profits with limited water availability.

Analysis of Farming Business Results

Net income is obtained by subtracting production costs from production results and then multiplying by the product price. Net income data will be used as a reference for choosing the ideal planting pattern. The analysis result can be seen in table 9 below.

Table 9. Analysis of farming business results in 2022 in Mojokerto Regency

No	Description	Type of plant	
		Paddy	Crop
1	Product price (Rp/ton)	6.436.000	4.800.000
2	Productivity (Tons/Ha)	6,88	6,65
3	Production Results (Rp/ton)	44.279.680	31.920.000
4	Production Costs (Rp/ton)	21.342.000	18.212.000
5	Profitability (Rp/ton)	22.937.680	13.708.000

Source: Mojokerto Regency Agriculture and Plantation Service 2022

Plant Intensity

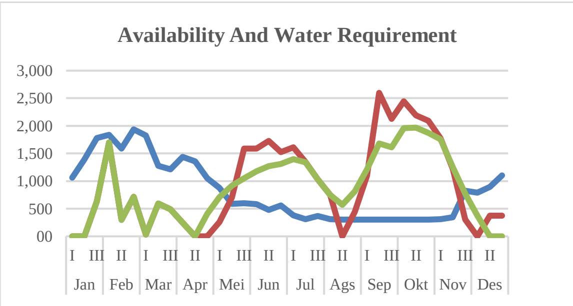
The results of optimization calculations carried out using the QM for Windows program show a maximum planting area of 2088 ha, which was obtained from adding up the optimization results for each type of plant. The amount of planting intensity can be described as follows:

$$\text{Plant intensity} = \frac{\text{planting area x 100\%}}{\text{raw area of fields (1055 Ha)}}$$

The highest crop intensity was produced from planting patterns 2,3,5 and 6 at 200%.

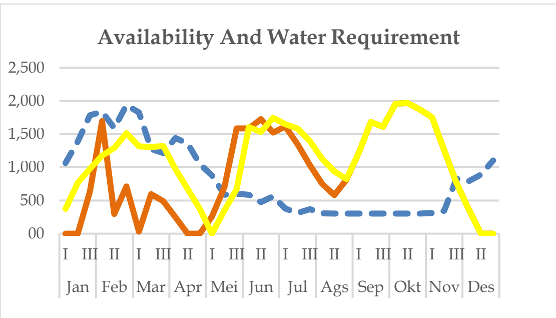
Availability And Water Requirement

The calculation results, which are presented in the graphic image 3 & 4 below, before increasing the discharge from the water pump. The result show the relationship between the availability of irrigation water in the Kromong II Irrigation Area and each cropping pattern choice.



Picture 3. Graph of availability and need for irrigation water for planting pattern 1 and 3

The blue line shows the availability of water discharge, the red line shows the water requirements for planting pattern 1, the green line shows the water requirements for planting pattern 3.



Picture 4. Graph of availability and need for irrigation water for planting pattern 2 and 4

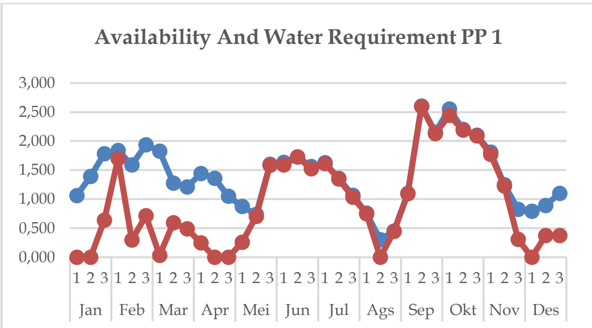
The blue line shows the availability of water discharge, the orange line shows the water requirements for planting pattern 2, the yellow line shows the water requirements for planting pattern 4. There are many water shortages due to the lack of additional suffice water pumps.

Well Drilling Pump Demand

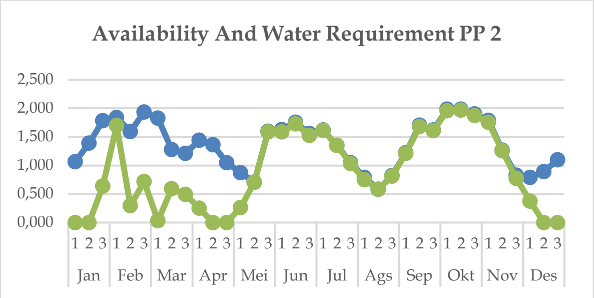
To fulfill the water needs of plants in raw rice fields that lack water, creating drilled well irrigation is an alternative solution to this problem. Based on the results of the water balance analysis above, it was found that there was a significant water shortage problem, especially during the dry season, so in this research drilled wells were used to help provide water needs in order to maximize farmers' harvests in the Irrigation Area of Kromong II. Example of calculating five pump wells with a capacity of 20 lt/sec/day for the planting pattern 1:

1. Calculate the amount of water shortage/deficit
   Deficit = water demand debit - availability debit
   = 1587 – 600,32 lt/sec
   = 986,72 lt/sec
2. Calculation of operation pump hours
   Operation $= \frac{\text{water deficit}}{\text{Pump Capacity}}$
   $= \frac{3552{,}18}{360}$
   = 10 hour/day
3. Total discharge availability after adding pumps
   Total = Pump capacity x pump operation
   = 360 x 10
   = 3600 m^3/hour
   = 1000 lt/sec

Based on the results of optimization calculations with the addition of the pump well above, a graph of water availability and demand for the planting pattern is obtained as follows:
graph of water availability and demand for the planting pattern is obtained as follows:



Picture 5. Graph of increase in water availability with drilled wells in planting pattern 1



Picture 6. Graph of increase in water availability with drilled wells in planting pattern 1

According to the graph, plant water needs in both planting patterns 1 and 2 can be met with additional water from pump wells.

Farmer Business Optimization Analysis

The optimal profit value is obtained from harvest production minus business costs and minus pump operating costs. The highest result from the six alternative planting patterns is the maximum profit value that farmers can get. The example calculation:

1. Exsisting =12.099.630.000,00-39.600.000,00 -0
   = 11.956.952.200,00
2. PP 1= 47.892.690.000,00-39.600.000,00 – 103.077.800,00
   = 47.750.012.200,00
3. PP 2= 43.331.500.000,00-36.270.000,00 – 118.768.800,00
   = 43.176.461.200,00
4. PP 3= 38.661.190.000,00-32.940.000,00 – 108.871.400,00
   = 38.519.378.600,00
5. PP 4= 40.572.310.000,00-32.940.000,00 – 121.907.000,00
   = 40.417.463.000,00
6. PP 5 = 31.587.300.000,00 - 32.940.000,00 –88.111.000,00
   = 31.466.249.000,00
7. PP 6 = 28.923.880.000,00-29.610.000,00 –88.111.000,00
   = 105.733.200,00

After considering the expensive cost of constructing wells and the significant demand for secondary crops in the community, it has been determined that the most appropriate and efficient planting pattern is planting pattern 2 (Paddy-paddy-crop). This planting pattern only requires four pumps and has the potential to generate a profit of IDR 43,176,461,200.00,- while also addressing the water needs of the community.

V. CONCLUSION

The conclusions drawn from the results of the analysis and calculations are as follows:

1. Water availability in the Kromong II Dam Irrigation Area was found to have the largest reliable discharge in February Period III of 1936.69 lt/s and the lowest of 303.00 lt/s in September and October.channel was found to have the largest reliable discharge in February Period III of 1936.69 lt/s and the lowest of 303.00 lt/s in September and October.
2. Average Water availability in the Kromong II Dam Irrigation water requirements based on 6 alternative cropping patterns as follows:
   a. Planting pattern 1 is paddy-paddy-paddy at 941,37 lt/sec.
   b. Planting pattern 2 is paddy-paddy-crop, at 908,44 lt/sec.
   c. Planting pattern 3, is paddy-crop-crop, at 886,93 lt/sec.
   d. Planting pattern 4, is crop-paddy-crop, at 1109,58 lt/sec.
   e. Planting pattern 5, is crop-crop-paddy, at 1060,77 lt/sec.
   f. Planting pattern 6, is crop-crop-crop, at 1089,99 lt/sec.
3. Optimum planting pattern obtained from the results calculation of the QM for Windows assistance program with profit optimization results using 4 additional pump wells with a capacity of 20 lt/sec. Optimization results were obtained with a paddy - paddy - crop planting pattern with a planting intensity of 200% with a profit value of IDR 43,176,461,200, - where the profit was greater from the previous existing condition without the addition of a pump only get a profit of Rp 11,956,952,200,00

REFERENCES

Efrida, R., Sitompul ,M. (2018). Evaluasi Ketersediaan Air DAS Deli Terhadap Kebutuhan Air (Water Balanced). *Jurnal Ilmiah Teknik Sipil Universitas Andalas*, 14(2).

Ferdiansyah, E., & Saves, F. (2023). Optimasi Ketersediaan Dan Kebutuhan Air Irigasi Di Daerah Irigasi Ketandan Kabupaten Kediri Menggunakan Program Linier. *Jurnal Ilmiah Teknik Dan Manajemen Industri*, 3(1). Https://Doi.Org/10.46306/Tgc.V3i1

Ivana, V., Liany, K., Hendratta, A., & Wuisan, E. M. (2015). Analisis Ketersediaan Air Sungai Talawaan Untuk Kebutuhan Irigasi Di Daerah Irigasi Talawaan Meras Dan Talawaan Atas. *Jurnal Ilmiah Teknik Sipil Universitas Sam Ratulangi Manado*,13(64).

Laksitaningtyas, A. P. (2016*). Sistem Irigasi Desa Kasang Lopak Alai. . Jurnal Ilmiah Teknik Sipil Universitas Atmajaya Yogyakarta*, (Vol. 13, Nomor 4).

Kementerian Pekerjaan Umum.(2013). *Kriteria perencanaan bagian perencanaan irigasi KP 01 tentang Standar Perencanaan Irigasi.* Jakarta : Kementrian Pekerjaan Umum dan Perumahan Rakyat.

Mushthofa., & Ikhwan, Z. (2022). Optimasi irigasi dengan penyesuaian pola tanam. *Jurnal Ilmiah Teknik Sipil Unigoro,3*(1*),* 7(2).

Noerhayati, E., Suprapto, B., & Syahid, A. A. (2017). Peningkatan keuntungan melalui optimasi sistem pemberian Air Daerah Irigasi Molek dengan program linier. *Jurnal Ilmiah Teknik Universitas Islam Malang*,3(1),9(1).

Pola, S. O., Daerah, T., Gong, I., Parang, G. K., Magetan, K., Setyono, E., & Mucharom, S. (2016). Studi optimasi pola tanam Daerah Irigasi Gong Gang Kecamatan Parang Kabupaten Magetan, *Jurnal Ilmiah Teknik Sipil Universitas Muhammadiyah Malang,* 14(1).

Pratiwi, V., & Sofandi, H. (T.T.). (2022). Analisis kehilangan air pada saluran Irigasi Daerah Irigasi Sudi Mampir Kecamatan Rancaekek Kabupaten Bandung. *Civil Engineering Research Journal,* (Vol. 3).

Priyonugroho, A. (2014). Analisis kebutuhan air irigasi (studi kasus Pada Daerah Sungai Air Keban Daerah Kabupaten Empat Lawang. *Jurnal Ilmiah Teknik Sipil Universitas Sriwijaya,* 2(3).

Program, D. S., Magister, S., Sumber, P., Air, D., Harlan, D., Keahlian, K., Sumber, T., Program, W., Teoretis, J., Bidang, T., Sipil, R., Terapan, D., Rekayasa, B., & Abstrak, S. (2016). Model optimasi pola tanam untuk meningkatkan keuntungan hasil pertanian dengan program linier (Studi kasus Daerah Irigasi Rambut Kabupaten Tegal Provinsi Jawa Tengah). . *Jurnal Teoritis dan Terapan Bidang Rekayasa Sipil*, *23*(2).

Samsugi, S., Mardiyansyah, Z., & Nurkholis, A. (2020). Sistem pengontrol irigasi otomatis menggunakan mikrokontroler Arduino Uno). *Jurnal Ilmiah teknik Sipil,* 01(01).

Saputra, F. (2018). Analisis ketersediaan dan kebutuhan air irigasi untuk pertanian di Kecamatan Padang Ganting Kabupaten Tanah Datar. *Jurnal Ilmiah Studi Geografi Universitas Negeri Padang*, 2(2).

Sari, Dian P., Anwar, N., & Shidarti, T. S. (2019). Analisis kesiapan modernisasi irigasi pada daerah irigasi kewenangan pemerintah provinsi di Kabupaten Mojokerto. *Jurnal Ilmiah Irigasi,* 14(1).

Saves, F., Soebagio, S., & Widodo, W. T. (2022). Optimalisasi keuntungan produksi tanaman menggunakan program linear berdasarkan pola tata tanam. *Radial: Jurnal Peradaban Sains, Rekayasa Dan Teknologi*, *10*(1), 144–153. Https://Doi.Org/10.37971/Radial.V10i1.247

Setiadi, D., Nurdin, M., & Muhaemin, A. (2018). Penerapan *Internet Of Things (Iot)* pada sistem monitoring irigasi (smart irigasi). *Jurnal Infotronik, 3*(2).

Setyawan., Andiese, V,M., & Anzar, L, A. (2017). Analysis of water availability with F.J Mock Method on the regional area of poboya village in Palu Central Sulawesi Setiyawan. *Jurnal Ilmiah Teknik Sipil Tadulako,* 7(1).

Sitompul, M., & Efrida, R. (2018). Evaluasi ketersediaan air DAS Deli terhadap kebutuhan air (water balanced). *Jurnal Rekayasa Sipil (Jrs-Unand*), *14*(2), 121. Https://Doi.Org/10.25077/Jrs.14.2.121-130.2018

Steven Witman. (2021). Penerapan metode irigasi tetes guna mendukung efisiensi penggunaan air di lahan kering. *Jurnal Triton*, *12*(1), 20–28. Https://Doi.Org/10.47687/Jt.V12i1.152

Syahputra, I., Blang Bintang, J., Km, L., Keude, L., & Besar, A. (2015). Analisis ketersediaan air pada daerah irigasi blang karam Kecamatan Darussalam Kebupaten Aceh Besar. *Jurnal Teknik Sipil Unaya*, 1(1).