Optimization Cropping Pattern of Palaan Secondary Plot Ngajum Irrigation Area Malang Regency

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Abstract. Palaan Irrigated Paddy Field Area is in Malang Regency. Paddy field production strongly supports food security. The problem of the efficiency of irrigation canals in paddy fields causes water availability to decrease. Preliminary observations showed that the total efficiency of irrigation canals was 61.48% (64% in plot I and 92.17% in plot 2). In addition, farmers also have difficulty determining cropping patterns due to erratic weather. This study aimed to determine the water balance in Palaan irrigated paddy fields and identify the optimization of cropping patterns. The method used to determine the water balance is by evaluating the availability of irrigation water and irrigation water requirements. Irrigation water requirements are calculated using Cropwat 8.0 software. The availability of irrigation water is obtained based on canal discharge data and measurements of irrigation canal discharge in the field. The SOLVER linear program in Microsoft Excel is also used in the Identification process for optimizing cropping patterns. The results showed that there was a water surplus in plots 1 and deficit in plots 2. The condition occurred due to a less-than-optimal cropping pattern. Optimization of cropping patterns is very important to obtain cropping patterns that are in accordance with the maximum utilization of water availability. The function of optimization constraints is the availability of land area and the availability of irrigation canal discharge. The cropping patterns resulting from the optimization of plots 1 and 2 were Paddy- Paddy- Paddy Palawija and Paddy Palawija- Palawija- Palawija, respectively. The optimal land area in plot I is the paddy planting period I and II, with an area of 11.42 ha. Paddy Palawija planting period III was 6.28 ha and 5.14 ha respectively. Paddy Palawija planting area in plot 2 periods I was 3.69 ha and 29.76 ha respectively. Palawija planting period II and planting period III were 19.68 ha and 7.11 ha respectively. This research will be helpful for farmers, irrigation managers, and stakeholders in the agricultural sector to improve regional food security.

Keywords: Optimization, Cropping pattern, Irrigation area

1 Introduction

Agricultural plants need water to grow and develop. Plants that lack water will have a negative impact on the process of growth and production, so that water needs that are met properly will result in maximum production [1]. The role of water in plants is

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maintained plant temperature, photosynthesis process, respiration, media for biochemical reactions, and process of absorbing minerals from the soil [2].

Water has dynamic or changing properties, both natural and human-influenced, so that water that initially fulfills needs turns into water availability but cannot meet needs [3]. Plant water needs to be known because it is related to the plant's living needs and its use for the plant. Research conducted [4] on the Water Balance in the Cimandiri irrigation area showed that there was a water shortage (deficit) in October and November of the first decade. The water balance of the Ciliman irrigation area also showed a significant water shortage (deficit). Occurs in the dry season, namely June I to November II [5]. Currently, the trend is an imbalance between water availability and water demand [6]. Based on several studies, it shows that there is a planting period that lacks water. Optimizing planting patterns, such as comprehensive analysis of agricultural areas using mathematical programs or linear programs, needs to be carried out as a form of anticipation in times of water shortages or water deficits [7].

Preliminary observations showed there is a problem in the Palaan secondary plot Ngajum irrigation area. Problems that occur is the low efficiency of secondary, tertiary irrigation canals. Total efficiency was 61.48%. Channel primary and secondary irrigation in conditions well the efficiency is 90-95%, while the channel tertiary 80-87.5%. Deep channel efficiency in real conditions in the field can only about 60-70%. However, in Irrigation channel planning is not recommended, efficiency is only 60-70% [3].

Based on asset data from the Malang Regency irrigation area, the secondary plot of Palaan DI Ngajum consists of 2 plots, namely plot 1 and plot 2. The results of measurements carried out by researchers in the field. The efficiency of the irrigation channels for each plot is 64% and 92.17% [8]. Irrigation canals in Indonesia experienced light to severe damage, as much as 52%. Canal damage can reduce irrigation efficiency. This condition causes inefficient irrigation services to support agricultural production [8].

The efficiency of the irrigation canal is the channel's ability to carry water from the source to the land of agriculture for plant use [9]. Water flow on the irrigation canal from the source to lost agricultural land water due to seepage, leakage, evaporation, and water exploitation by society. Small irrigation efficiency indicates that there is a loss of water large before reaching the ground of agriculture. Loss of water, causing reduced availability of water for plant use [10].

Another problem that occurs is Farmers have difficulty predicting the weather. The weather is difficult to predict because of climate change events, thus arising confusion in determining the pattern of plant. Irrigation modernization needs to be done in dealing with the effects of change climate to achieve irrigation management effective [8]. In the existence of these problems, it is necessary to do research on optimizing cropping patterns in accordance with conditions in the field.

The purpose of this study was to determine the existing water balance and optimize cropping patterns. Optimization is done to increase the planting index (PI). The results of this study can provide benefits to local farmers, irrigation managers, and the Malang Regency Water Resources Public Works Department.

2 Materials and Method

2.1 Method

This study used a quantitative method with a descriptive level of analysis. Quantitative method is a method of data collection, interpretation, and display of results using numbers [11]. Quantitative research presented numerical data from calculations of the existing water balance and optimization of cropping patterns. The level of descriptive analysis aims to describe phenomena that occur in real terms and are actual in the field [4].

2.2 Research Flow Chart

The research was conducted in a structured manner based on the planned stages. The flowchart provides a systematic overview of the research conducted. The flowchart of this research is in Figure 1.

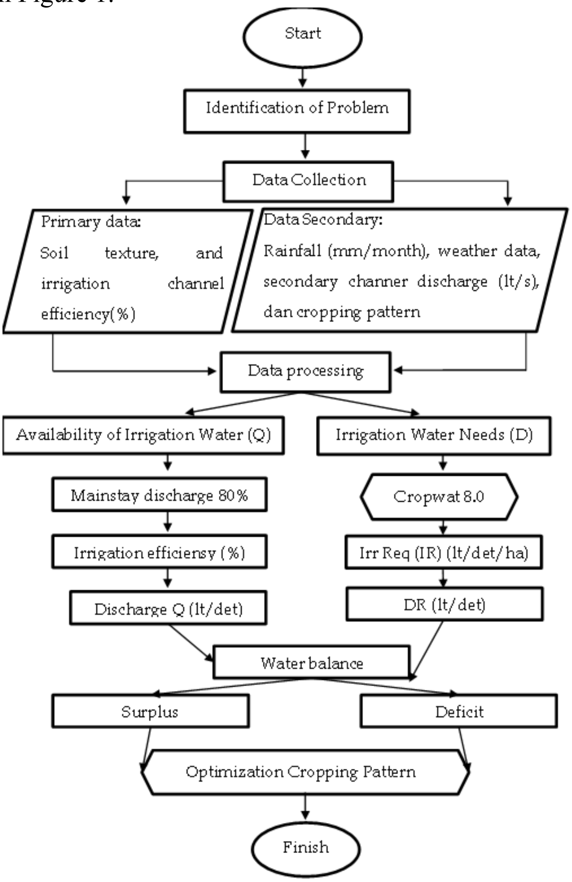

Fig. 1. Research Flow Chart

2.3 Research Site

The research was conducted in secondary plots of Palaan Irrigation Ngajum Malang Regency. The map of the research location is shown in Figure 2. The coordinates of the location are between 112^{0}32'38" E to 112^{0}33'05" E and 8^{0}5'58" S to 8^{0}6'50" S. This plot is divided into two parts. Plot 1 has an area of 11.42 Ha, while plot 2 has an area of 33.45 Ha. The total area of all plots is 44.87 Ha. Administratively it is located in the village of Palaan, Ngajum district, Malang regency.

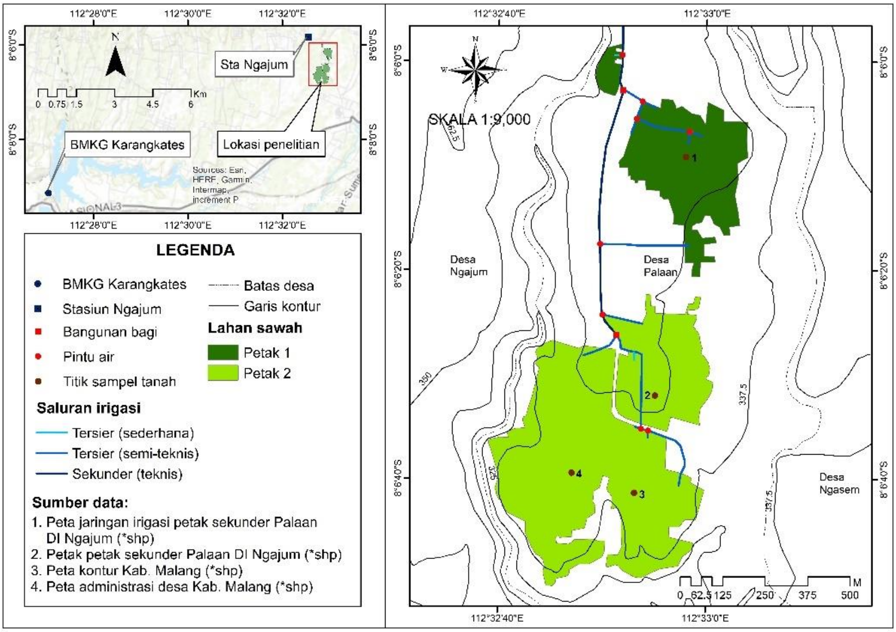

Fig. 2. Research Location Map

2.4 Data Collection

The data used are primary data and secondary data. Primary data obtained by researchers from the results of direct measurements in the field. Primary data consists of secondary-tertiary irrigation canal efficiency data, and soil texture data. Secondary data is obtained from certain reports or literature. Secondary data consists of monthly cumulative rainfall data for the Ngajum station in 2013-2022, data on the intake channel discharge for the intake weir in Ngajum in 2013-2022, the Ngajum Irrigation Area Global Planting Plan for 2017-2018, and BMKG Karangkates weather data which includes air temperature, relative air humidity, wind speed, and sunshine duration in 2013-2022. Types and sources of data in Table 1.

Table. 1. Data Types and Sources

Data	Data Types	Sources
Channel efficiency	Primary	Field measurements and laboratory tests
Soil texture		
Rainfall	Secondary	Malang Regency Water Resources Public Works Department
Channel discharge		
Global cropping plan		
Weather data		BMKG Karangkates

2.5 Data Processing Techniques for the Availability of Irrigation Water

The availability of irrigation water comes from intake discharge data from the Palaan secondary canal in Ngajum. Discharge data processing is divided into two stages, namely calculating the mainstay discharge, and the efficiency of irrigation canals. The purpose of calculating the reliable discharge is to estimate the minimum discharge of the channel that is likely to be fulfilled in order to guarantee the planning needs of an irrigation project [12]. The purpose of calculating the channel efficiency is to determine the discharge of water that reaches agricultural land [9].

Mainstay discharge is the amount of water availability that is likely to be sufficient with the risk of failure that has been planned [11]. Irrigation planning is determined by the mainstay discharge of 80% with a lower failure than the mainstay discharge of 20% [12]. Calculation of the mainstay discharge using the Weibull method with equation 1. Probability (P) is obtained by dividing the data serial number (m) by the amount of data (n) plus 1 multiplied by 100% [4].

$$P = \frac{m}{n+1} \times 100\% \quad (1)$$

Irrigation canal water flow to agricultural land there is a factor of water loss. Water loss (WT) is caused by leakage/seepage, evaporation, and water exploitation by the community [10]. Therefore, the mainstay debit is processed with the efficiency value of irrigation canals to determine the amount of available water that can be utilized by agricultural crops.

The efficiency of irrigation canals is the ratio of the discharge of water that reaches agricultural land to the discharge at the floodgates [13]. The efficiency assumption is that if the water loss is high, the efficiency will decrease and vice versa [14]. The efficiency of irrigation canals is measured by the inflow-outflow method or the water balance technique in the canal sections. Measurements were made with a current meter at the water intake and water entering the land. Time of measurement in March 2023 when the weather is sunny. Calculation of discharge and efficiency of irrigation channels is stated in equations 2 and 3 [9]. The channel discharge (Q) (m3/s) is obtained from the wet cross-sectional area (A) (m2) multiplied by the flow velocity (V) (m/s). Irrigation channel efficiency (%) is obtained by dividing the outflow (O) (liters/second) by the inflow (I) (liters/second) multiplied by 100%.

$$Q = A \times V \quad (2)$$

$$ef = \frac{O}{I} \times 100\% \tag{3}$$

2.6 Data Processing Techniques for Irrigation Water Needs

The need for irrigation water is the water needed to meet evapotranspiration, and water loss by considering rainfall and groundwater [15]. Irrigation water needs are calculated using the Cropwat 8.0 software. Cropwat is software developed by the Land and Water Development Division of FAO (Food and Agriculture Organization) as a tool for calculating irrigation water needs [16]. The advantages of Cropwat 8.0 are that it can calculate irrigation water needs, develop irrigation schedules, and practically calculate water supply schemes for various cropping patterns by entering the required parameters. The drawback of Cropwat is that it is still not understood by farmers and the results of the data are influenced by the rounding that is done [14].

Cropwat 8.0 requires data input in order to be able to calculate irrigation water needs. The data needed to include rainfall, weather data (air temperature, relative humidity, wind speed, and duration of solar radiation), crop data/global planting plan, and soil texture data. Input Cropwat 8.0 data in table 2.

Table. 2. Input Cropwat 8.0 Data

Data	**Result**
Rainfall	Water availability
Weather	Potential evapotranspiration
Global cropping plan	Plant factor
Soil texture	Maximum infiltration, maximum rooting depth, and initial soil moisture depletion.

Calculation of irrigation water needs using Cropwat 8.0 is divided into three stages. The first stage is to calculate crop water requirements (CWR) in equation 4. The second stage is to calculate irrigation requirements (IR) in equation 5. The third stage is to calculate water intake requirements (DR) in equation 6 [17]. The Cropwat 8.0 calculation method is based on a linear interpolation calculation algorithm, so that the input data in the form of monthly data produces a value of irrigation water needs in a period of 10 days [16].

$$CWR = ETo \times Kc \tag{4}$$

$$IR = CWR - Reff \tag{5}$$

$$DR = \frac{IR}{8.64} \tag{6}$$

CWR (mm/decade) is calculated by multiplying the potential evapotranspiration (ETo) by the crop coefficient (Kc). IR (mm/decade) calculated from CWR minus effective rain (Reff). The need for water at the intake gate (DR) is obtained from the division of IR with the conversion rate from mm/decade to liters/second/ha. Rain data processing is done before entering Cropwat. Processing is done in 2 stages. The first stage is to calculate the mainstay rain. The second stage is to calculate the effective rain. The purpose of relying on rain data is to find out the minimum average rainfall that can be used for irrigation purposes. The mainstay rain is used to calculate the effective rain. Rain is effectively utilized by plants in their growth process [11]. Paddy and palawija crops are determined to be 80% reliable rainfall (R80) [17]. The Weibull method in equation 1 is used in calculating reliable rainfall [4].

Effective rain is rain used by plants during their growth [18]. Rainfall that has decreased in intensity or is low can cause the amount of water available to be insufficient for plant growth [11]. Effective rainfall for paddy is a fixed percentage of 70% of R80, while palawija are 50% of R80 then using the USDA soil conservation service equation at Cropwat 8.0. In the following, equation 7 is presented to calculate the effective rainfall for paddy, while equations 8 and 9 are for crops [17]. P is the rainfall. Equation 8 is used if P <=250/3 mm. Equation 9 is used if P > 250/3 mm.

$$Reff\ Padi = R80 \times 70\% \tag{7}$$

$$Reff\ Pal \ = \frac{P \times (125 - 0.2 \times 3 \times P}{125} \tag{8}$$

$$Reff\ Pal \ = \frac{125}{3} + 0.1 \ \times P \tag{9}$$

Weather data includes air temperature (^{0}C), relative air humidity (%), wind speed (m/s), and sunshine duration (hours). The data is used to calculate the value of potential evapotranspiration (ETo). Potential evapotranspiration (ETo) is evapotranspiration that occurs in reference plants, namely grass plants that grow on land with a plant height of 12 cm from the ground surface and their water needs are properly fulfilled [19].

Potential evapotranspiration (ETo) was calculated using Cropwat 8.0. The calculation method is FAO Penman-Monteith. This method uses maximum weather data such as temperature, relative humidity, wind speed, and sunshine duration, so it has a high degree of accuracy compared to other methods [20]. The amount of potential evapotranspiration is needed to calculate the water requirement for plants. The water requirement for plants (CWR) is obtained by multiplying the crop coefficient (Kc) and potential evapotranspiration (ETo) in equation 4. Equation 10 is used to calculate potential evapotranspiration (ETo) by the FAO Penman-Monteith method [21]. Rn is the net solar radiation over the plant surface (MJ/m^2/day). T as the average air temperature (^{0}C). U2 is the wind speed at a height of 2m above the ground (m/s). Saturated water vapor pressure (kPa) as es. Actual water vapor pressure (kPa) as ea. The slope of the water vapor pressure curve with respect to temperature (kPa/^{0}C) as Δ. Psychometric constant (kPa/^{0}C) as γ.

$$ETo = \frac{0{,}408\Delta Rn + \gamma\ 900/(T+273) U{\downarrow}2(es-ea)}{\Delta + \gamma(1+0{,}34U{\downarrow}2} \tag{10}$$

Plant data is sourced from the Ngajum Irrigation Area Global Planting Plan for 2017-2018. The data is used to determine the type of planting, planting date, crop coefficient value (Kc), rooting depth, inundation depth (paddy), critical depletion fraction (p), and yield response factor (Ky). Plant types and planting dates are based on global cropping plan data, while the others are based on the FAO database on Cropwat 8.0 according to the planned crop types [16].

Soil texture is obtained from taking soil samples in the field and laboratory test results. Soil samples were taken at 4 location points in a spread manner taking into account the type of soil and contours, which can be seen in Figure 2. The depth of sampling is approximately 0-30 cm below the soil surface. Location of soil sampling on the back of the paddy field. The assumption used is that the soil on the back of the paddy fields basically comes from the paddy fields. Soil sampling in Figure 3.

Fig. 3. Soil Sampling

Determination of soil texture based on the soil texture triangle (Figure 4). The results of soil texture classification are entered in the Cropwat 8.0 database options. Soil texture data is needed to determine the maximum infiltration rate, maximum rooting depth, and initial soil moisture depletion [16].

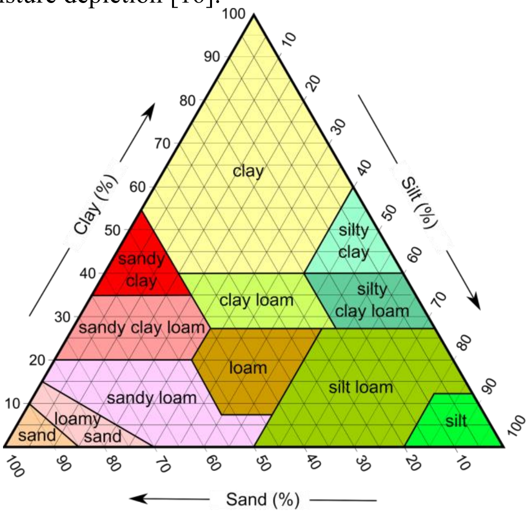

Fig. 4. The Soil Texture Triangle

2.7 Optimization Model Formulation Techniques

The Solver program on Microsoft Excel is used in the formulation of cropping pattern optimization models. Solver is one of the facilities in Microsoft Excel to find solutions. The advantages of this program are easy processing, can solve various constraints, simple mathematical functions, and pretty good calculation results [22]. The formulation of the optimization model has 3 things that must exist, namely the determination of the decision variable, the objective function, and the constraint function. The decision variable is the area of land for each alternative cropping pattern. The planned cropping pattern is Paddy (X1a-X3c), and Palawija (X4a-X5c). The objective function (Z) is to increase the cropping index (PI) by maximizing the need for water (D) if there is excess water or a surplus, and minimizing the need for water if there is a shortage of water or a deficit in the planned cropping pattern. The objective function model can be seen in equation 11 [9].

$$Z = D1a.X1a + D4a.X4a + D2b.X2b + D5b.X5b + D3c.X3c + D6c.X6c \quad (11)$$

The constraint function is determined by 2 aspects, namely the availability of land and water. The conditions for the land used are the optimal land area for each cropping pattern (X) must be smaller than the available land area (Xt). Provisions for water availability, namely the water requirement (D) cropping pattern (X) during the planting period (a) must be less than the total water availability (Qt). The constraint function model can be seen in equations 12 and 13 [9].

$$X1a + X2b + X3c + X4a + X5b + X6c \leq Xt \quad (12)$$

$$(D1a.X1a) + (D2b.X2b) + (D3c.X3c) + (D4a.X4a) + (D5b.X5b) + (D6c.X6c) \leq Qt \quad (13)$$

3 Discussion

3.1 Availability of Irrigation Water

The availability of irrigation water is analyzed based on the reliable discharge of 80% (R80) and the estimated water that reaches agricultural land. Irrigation water that reaches agricultural land is known from the measurement of discharge efficiency of irrigation canals. Calculation of the efficiency of irrigation canals is done in each plot, and in total. Measurement locations can be seen in Figures 5 and 6. Calculation of the efficiency of the secondary-tertiary irrigation canals is in Table 3. The measurement results show that the total efficiency of all plots is only 61.48%. The efficiency of plot 1 is 64%, and plot 2 is 92.17%. The low efficiency in plot 1 causes the water discharge in plot 2 to get smaller.

Reliable debit 80% (R80) is a debit with 80% probability of availability and 20% risk of failure. The reliable debit is then multiplied by the efficiency of the irrigation channel to find out the water discharge that can be used by plants. The initial inlet water flow is I1. Flow I1 exits to plot 1 of agricultural land through output 1 (O1) to output 6 (O6) and flows into plot 2 (I2). Flow I2 is supplied to plot 2 via output 7 (O7) to output (O12).

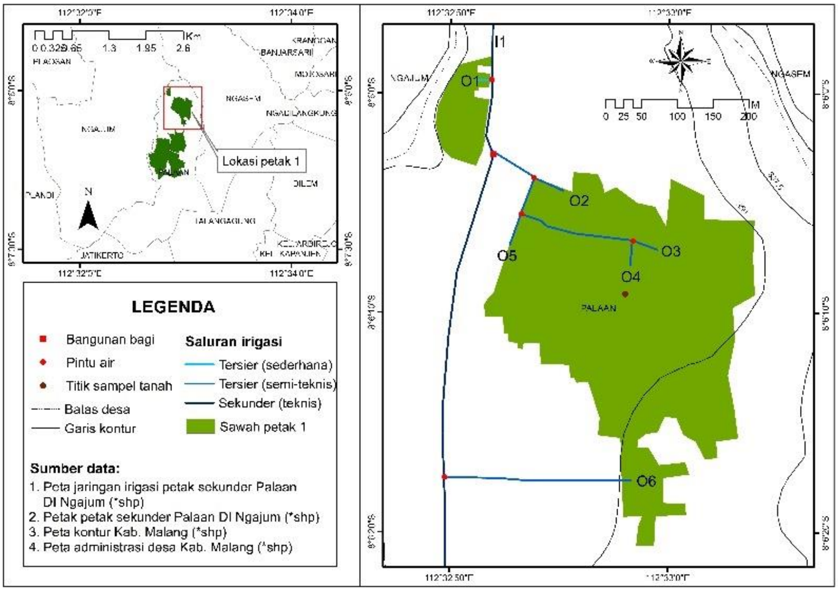

Fig. 5. The location of the measurement point for the discharge efficiency of the plot 1 irrigation canal

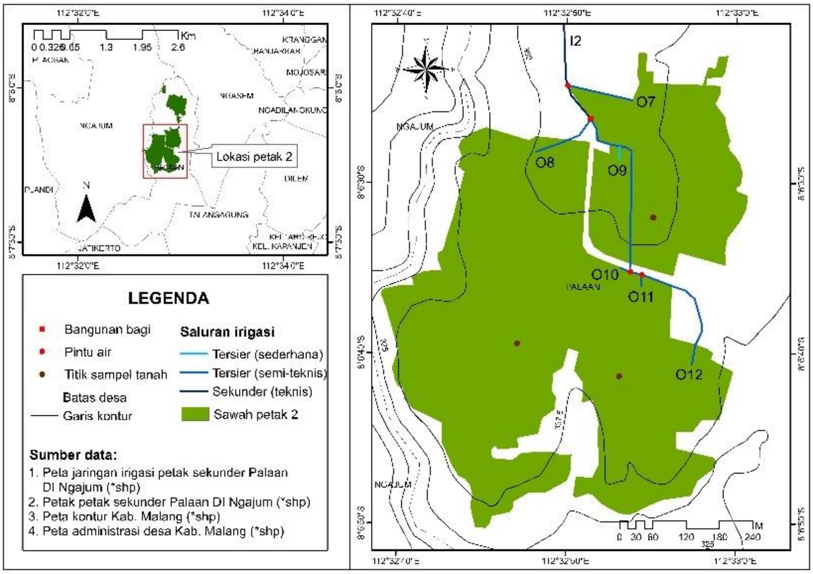

Fig 6. The location of the measurement point for the discharge efficiency of the plot 2 irrigation canal

The flow of I2 is 33% of the flow of I1. The total efficiency is calculated based on the inflow I1, and outflow as the output streams 1 to 12 and the inflow of plot 2 (I2). The results of the calculation of R80 and the efficiency of irrigation canals for each plot can be seen in Figure 7. The most abundant water availability occurs in February decade III, while the least is in September decade III to November decade I.

This incident was caused by the availability of irrigation water, which was influenced by the intensity of rainfall [23]. Table 5 shows that in January - April the effective rainfall is higher than other months by >100 mm, while in July - October the effective rainfall is 0 mm. This condition is related to the availability of irrigation water which shows the highest value in February of the third decade, and the lowest in September of the third decade to November of the first decade.

Table 3. Irrigation Canal efficiency calculation

Point		I1	O1	O2	O3	O4	O5	O6	I2	O7	O8	O9	O10	O11	O12
Discharge (lt/s)		124.93	7.8	3.03	2.98	6.58	3.71	15.26	40.64	9.75	7.65	1.8	10.5	2.1	5.67
Ef (%)	Plot	-					64						92.2		
	Total	-							61.48						

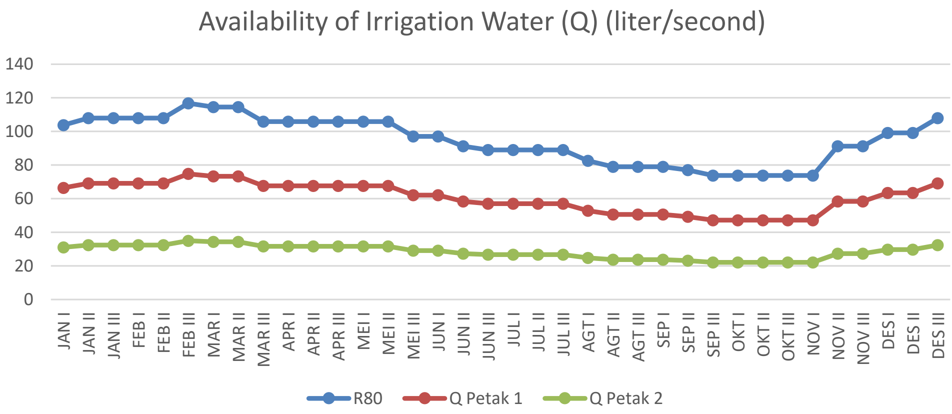

Fig. 7. Availability of Irrigation Water (Q)

3.2 Irrigation Water Needs

Potential Evapotranspiration (ETo)

Evapotranspiration is known based on BMKG Karangkates weather data. The distance from the weather station to the research location is approximately 10 km. A distance of

0-10 km from a weather station can represent local weather data [24]. ETo calculations can be seen in Table 4. Evapotranspiration is important to know in hydrometeorological analysis. Irrigation water needs are closely related to plant water needs or evapotranspiration.

The ETo value varies every month. The highest ETo occurs in October, while the lowest is in June. The amount of evapotranspiration is determined by solar radiation, wind speed, relative humidity and temperature. Factors that increase evapotranspiration include microclimate, plant factors, and soil factors [25].

Table 4. Potential evapotranspiration calculations

Month	Average air temperature	Relative air humidity	Wind velocity	Long sun exposure	Solar radiaton	ETo
	°C	%	m/s	jam	MJ/m²/hari	mm/hari
January	26.3	86	0.8	3.9	15.9	3.49
February	26	85	0.8	4.2	16.4	3.61
March	26.1	85	0.7	5.2	17.6	3.8
April	26.4	84	0.8	5.9	17.5	3.76
May	26.3	81	1	6.7	17.1	3.68
June	25.5	82	0.9	6.2	15.6	3.29
July	24.6	81	1.2	6.5	16.3	3.42
August	24.7	79	1.3	7	18.4	3.87
September	25.5	78	1.3	7.1	20	4.34
October	26.5	78	1.2	6.5	19.8	4.42
November	26.4	83	0.9	4.7	17.1	3.83
December	26.1	85	0.8	4	15.9	3.53
Average	25.9	82	1	5.7	17.3	3.75

Effective Rainfall

Effective rainfall is rain that is utilized by plants in their growth process. Plants need rain to fill water losses due to evapotranspiration, percolation, tillage and land preparation [7]. The calculation results can be seen in Table 5.

The most effective rainfall occurs in January, while the lowest occurs from July to October. The amount of effective rainfall is influenced by the intensity of rain and the type of plant. Paddy have a greater effective rain value than pulses. This is because paddy require more water than crops [9]. In general, in Java, the rainy season occurs from November to April, and the dry season from May to October. The Java-Bali region is included in the area whose rainfall pattern is influenced by the monsoon. The characteristics of the monsoon rain pattern are one peak and one valley in one year. The peak of rain usually occurs in January, while the peak of the dry season occurs in August [26].

Table 5. Effective Rainfall

Month	Effective rainfall (mm)		Month	Effective rainfall (mm)	
	Paddy	Palawija		Paddy	Palawija
January	177	100.8	July	0	0
February	149.4	88.5	August	0	0
March	160.4	93.6	September	0	0
April	105.1	66.1	October	0	0
May	33.5	23	November	166.6	96.3
June	8.1	5.7	December	173.6	99.4

Soil Texture

Soil acts as a medium for plants to grow. The physical properties of soil texture affect the ability of roots to penetrate, the ability to hold water, drainage, soil aeration, and nutrient potency [21]. The results of measuring the physical properties of soil texture can be seen in Table 6. Soil texture was dominated by silt loam at sample points 1, 2 and 4. Sample point 3 was textured with silty clay loam. The dominance of the loam texture is used to select the Cropwat 8.0 database. The medium (loam) soil classification was used for the soil factor in the Cropwat 8.0 data input (Figure 8).

Table 6. Soil texture

Point	Location	Soil texture (%)			Class
		Sand	Loam	Clay	
1	-8.102574 112.54942	7	69	23	Silt loam
2	-8.108926 112.54858	5	71	24	Silt loam
3	-8.111470 112.54788	4	58	38	Silty clay loam
4	-8.110978 112.54637	4	72	24	Silt loam

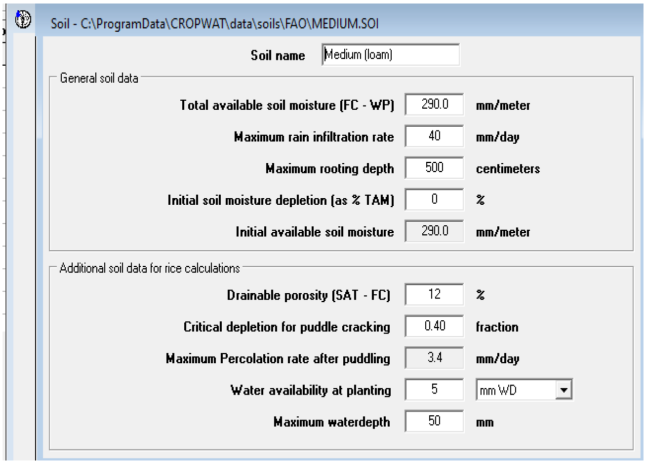

Fig. 8. Cropwat Soil Database

Existing Cropping Pattern

The Palaan secondary plot of the Ngajum Irrigation Area was divided into 2 plots. Plot 1 has an area of 11.42 ha, while plot 2 has an area of 33.45 ha. The total plot area is approximately 44.87 ha. The planned cropping pattern is based on the 2017-2018 Malang Regency global cropping plan. Plant input data in Figures 9 and 10.

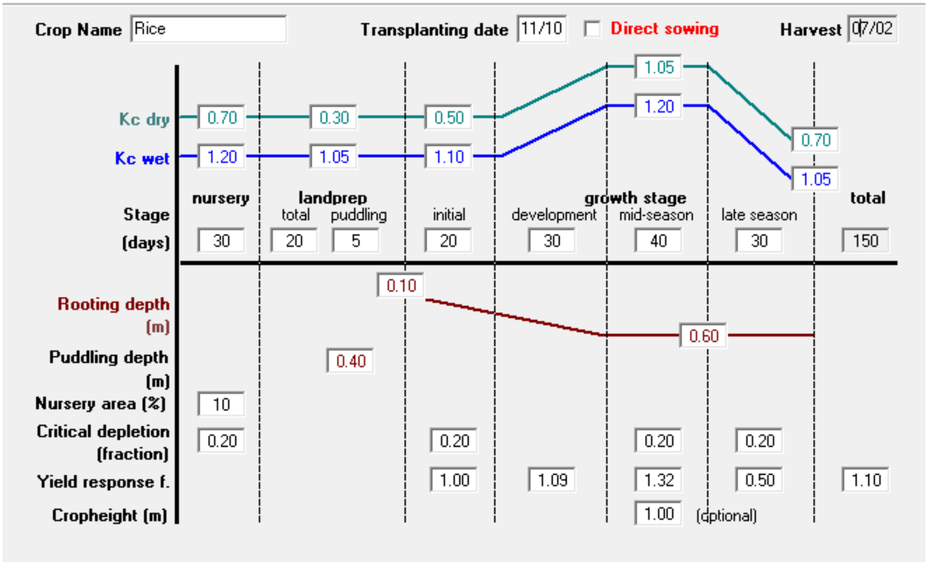

Fig. 9. Paddy Plant Inputs

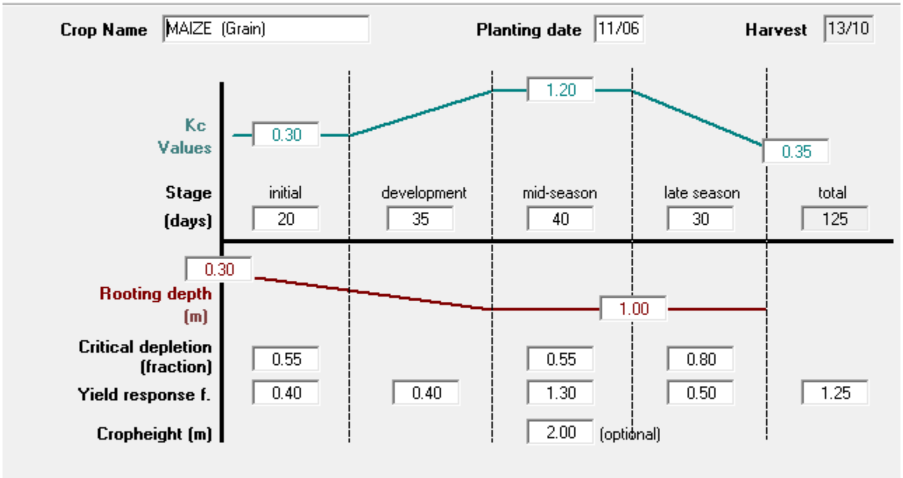

Fig. 10. Palawija Plant Inputs

The existing cropping pattern of secondary plots of Palaan is Paddy-Paddy-Palawija. Planting period I Paddy is planted in October decade 2. Planting period II, Paddy is planted in February decade 2. Planting season III, Palawija (maize) is planted in June decade 2. Plants are divided into several growth phases by FAO (Food and Agriculture Organization). The division of plant growth phases is based on the density of the leaves and the amount of standing water in 10 days. This phase consists of the Initial Stage (Init)/planting, the Development Stage (deve), the Mid-Season Stage/fruit ripening, and the Late Stage/harvesting. Especially for paddy, there are Nurs/nursery, and LPr (land preparation) phases. The purpose of dividing plant growth phases is to calculate irrigation water requirements [27].

Irrigation Water Needs

Crop water requirement (CWR) is influenced by potential evapotranspiration (ETo) and crop coefficient (Kc). Calculation of the need for irrigation water during the first planting period of paddy plots 1 and 2 is in Table 7.

Table 7. Irrigation water needs of planting period I Paddy plots 1 and 2

Month	Dec	Phase	Kc	CWR	Eff rain	IR	DR	DR P1	DR P2
			coefficient		mm/decade		lt/sec/ha	liter/second	
Sep	2	Nurs	1.2	5.2	0	5.2	0.6	6.87	20.13
Sep	3	LPr	1.06	46.5	0	96.4	11.16	127.42	373.22
Oct	1	LPr	1.06	46.8	0	213.8	24.75	282.59	827.73
Oct	2	Init	1.1	48.6	0	48.6	5.63	64.24	188.16
Oct	3	Deve	1.1	51.1	0.1	51	5.9	67.41	197.45
Nov	1	Deve	1.1	44.4	42.1	2.4	0.28	3.17	9.29

Nov	2	Deve	1.11	42.5	63.1	0	0	0	0.00
Nov	3	Mid	1.12	41.6	61.3	0	0	0	0.00
Des	1	Mid	1.12	40.6	57.2	0	0	0	0.00
Des	2	Mid	1.12	39.5	58	0	0	0	0.00
Des	3	Mid	1.12	43.3	58.3	0	0	0	0.00
Jan	1	Late	1.12	39.2	59.6	0	0	0	0.00
Jan	2	Late	1.08	37.8	60.4	0	0	0	0.00
Jan	3	Late	1.03	40.1	56.9	0	0	0	0.00
Feb	1	Late	0.99	24.7	36.2	0	0	0	0.00
			Average				3.22	36.78	107.73

The Kc value of paddy varies for each phase of plant growth. The largest paddy crop coefficient is in the Nurse/Nursery phase. In the land preparation (LPr) phase, the Kc value drops. In the init phase, deve (development) increases until the mid-session phase, then decreases again during the late-session phase. The increase in the value of Kc is due to the intensive evapotranspiration occurring during the init to mid-season phases. An increase in the Kc value causes the plant's water needs to increase. The decrease in the value of Kc in the late-season phase was due to the drying process occurring in that phase. During the drying process, the rate of evapotranspiration still occurs but is not intensive, so that the plant's water requirement is not too high [21].

Each phase of the paddy has different crop water requirements (CWR). CWR experienced a significant increase in the LPr phase, then gradually decreased in the Late phase. This condition is the same as the value of the crop coefficient. The highest crop water requirement occurs in the mid-season phase of October, decade 3, while the lowest is in the Nurs phase, September decade 2. Crop water demand is influenced by several factors such as climate, plant type, and plant growth phase [27].

The need for irrigation water is based on the value of irrigation requirements (IR). Crop water needs to utilize the availability of rainwater through effective rain before it needs water from the canal [17]. The need for irrigation water will be smaller if the rain is effectively able to meet the water needs of plants, so there is no need to fulfill water from irrigation canals. IR is influenced by topography, hydrology, climatology, and soil texture [28].

The water demand at the intake point (DR) is based on the IR value in different units, namely liters/second. DR takes into account the efficiency factor of the irrigation canal during flow. This is because during the flow of water in the channel there is water loss (water loss) from the efficiency factor, so that the amount of water at the intake gate is not the same as the water that reaches the agricultural land. Therefore, DR calculations need to be carried out in order to know the intake gate water needs to meet crop water requirements and the efficiency factor in irrigation canals.

The need for water at the intake gate (DR) during the first planting period in plots 1 and 2 was not always the same on each basis. The highest DR occurs in the LPr phase in October decade 1, while the lowest is in the Mid-November phase in decade 2 to the Late phase in February decade 1. The LPr phase occurs when there is a significant shortage of water. Paddy require large amounts of water during land preparation or land preparation (LPr) and planting (Init)[29]. The LPr phase is 2 decades or 20 days long. The last 5 days in the LPr phase there is a puddling process, so that in this phase the need for irrigation water increases significantly [16]. The average irrigation water requirement per hectare (ha) during the first planting period was 3.22 liters/second. Plot 2 requires more water than plot 1. This is affected by the larger service area. The larger area requires more irrigation water [25].

Table 8. Irrigation water needs of planting period II Paddy plots 1 and 2

Month	Dec	Phase	Kc	CWR	Eff rain	IR	DR	DR P1	DR P2
			coefficient		mm/decade		lt/sec/ha	liter/second	
Jan	2	Nurs	1.2	3.8	54.4	0	0.00	0.00	0.00
Jan	3	LPr	1.08	38	56.9	49.4	5.72	65.29	191.25
Feb	1	LPr	1.06	38	51.7	158	18.29	208.84	611.70
Feb	2	Init	1.1	39.7	48	0	0.00	0.00	0.00
Feb	3	Init	1.1	32.3	49.8	0	0.00	0.00	0.00
Mar	1	Deve	1.1	41.3	54.3	0	0.00	0.00	0.00
Mar	2	Deve	1.12	42.4	56.6	0	0.00	0.00	0.00
Mar	3	Deve	1.13	47	49.4	0	0.00	0.00	0.00
Apr	1	Mid	1.13	42.8	41.7	1.1	0.13	1.45	4.26
Apr	2	Mid	1.13	42.7	35.8	6.9	0.80	9.12	26.71
Apr	3	Mid	1.13	42.4	27.6	14.8	1.71	19.56	57.30
Mei	1	Mid	1.13	42	17.7	24.3	2.81	32.12	94.08
Mei	2	Late	1.11	40.9	9	31.9	3.69	42.16	123.50
Mei	3	Late	1.06	41.4	6.9	34.5	3.99	45.60	133.57
Jun	1	Late	1.01	34.5	5	29.5	3.41	38.99	114.21
			Rata-rata				2.70	30.88	90.44

Calculation of irrigation water needs during planting period II plots 1 and 2 in Table 8. The crop coefficient (Kc) has the same characteristics as planting period I because of the same type of plants. However, the values are slightly different. Plant water requirements (CWR) for Planting Period II varies from year to year. The highest CWR occurred in the Mid-April phase of decade 1, while the lowest was in the Nurs phase in January of the 2nd decade. This was the same as the Planting Period I with the highest CWR in the Mid-season phase and the lowest in the Nurs phase.

The largest irrigation requirements (IR) occur in the LPr phase in February decade 1, while the lowest is in the Nurs phase in January decade 2, and the Init phase in February decade 2 to the development (deve) phase in March decade 3. The demand for water at the intake gate (DR) follows IR with a different unit, namely liters/second. The average irrigation water requirement for MT II is 2.7 liters/second/ha. The LPr phase requires more water than the other phases. Rainfall has not been able to meet the needs of irrigation water in this phase. IR that is low or even zero or does not require water from irrigation canals is caused because the water needs have been fulfilled by effective rainfall. Effective rainfall from January to March is large enough to meet the needs of irrigation water. In April, the effective rainfall gradually decreases, so that it cannot meet the needs of irrigation water. Therefore, in the Mid-season phase of April decade 1 to the Late-season phase, water is needed from irrigation canals.

Table 9. Irrigation Water Needs for Planting Period III Palawija (maize) plots 1 and 2

Month	Dec	Phase	Kc	CWR	Effective rain	IR	DR	DR P1	DR P2
			coefficient		mm/decade		lt/det/ha	liter/second	
Jun	2	Init	0.3	9.9	1.4	8.4	0.97	11.10	32.52
Jun	3	Init	0.3	10	0.9	9.1	1.05	12.03	35.23
Jul	1	Deve	0.43	14.6	0.1	14.5	1.68	19.17	56.14
Jul	2	Deve	0.67	23.1	0	23.1	2.67	30.53	89.43
Jul	3	Deve	0.93	36.4	0	36.4	4.21	48.11	140.92
Aug	1	Mid	1.13	42.1	0	42.1	4.87	55.65	162.99
Aug	2	Mid	1.14	44.3	0	44.3	5.13	58.55	171.51
Aug	3	Mid	1.14	50.7	0	50.7	5.87	67.01	196.29
Sep	1	Mid	1.14	47.9	0	47.9	5.54	63.31	185.45
Sep	2	Late	1.07	46.5	0	46.5	5.38	61.46	180.03
Sep	3	Late	0.81	35.6	0	35.6	4.12	47.05	137.83
Oct	1	Late	0.55	24.1	0	24.1	2.79	31.85	93.30
Oct	2	Late	0.38	5	0	5	0.58	6.61	19.36
			Rata-rata				3.45	39.42	115.46

Plants during planting period III were crops palawija (maize), in contrast to planting periods I and II with paddy. Calculation of irrigation water needs for MT III plots 1 and 2 in Table 9. The crop coefficient (Kc) since the Init/planting phase has an upward trend. The Kc value decreased gradually in the Late/harvesting phase. The highest crop water requirements (CWR) occurs in the Mid-season phase in August decade 3, while the lowest is in the Late phase in October decade 2. The highest and lowest irrigation water requirements (IR) are the same as CWR. The need for water at the intake gate (DR) will follow IR.

The need for irrigation water has increased from the Init phase in June 2nd decade to the Mid-season phase in August 3rd decade. In the Mid-season phase in September 1st decade, it gradually decreases until the Late-season phase in October 2nd decade. The same trend in CWR, IR, and DR values occurred because during planting period

III there was very little rainfall. In June to October, there is almost no effective rainfall that can be utilized. The low effective rainfall causes the demand for water in irrigation canals to be large.

3.3 Existing Water Balance

Water balance is the process of comparing the need for irrigation water with the availability of irrigation water. The existing water balance aims to find out whether there is excess water (surplus) or water shortage (deficit) in the current conditions. Calculation of irrigation water balance during planting I plot 1 and 2 in Table 10. During the planting period I plot 1 water deficit occurred in the land preparation (LPr), init, and deve phases in September 3rd decade to October 3rd decade. The planting phase (init) in October 2nd decade and the young phase (deve) in October 3rd decade also experienced a deficit. The water deficit during the init and deve phases is not as big as the LPr phase. The water surplus occurs during the deve to late phase in November of the 1st decade to February of the 1st decade.

The need for water during the deve phase to the late November of the 1st decade to February of the 1st decade is little or even zero. In this phase there is a surplus of water. This condition occurs because the need for water has been sufficiently met by effective rainfall. From November to February, the effective rainfall is quite large, above > 100 mm, so that it can meet the needs of irrigation water. Overall during the first planting period plot 1 there was a surplus of water. During the planting period I plot 2 the water deficit and surplus occurred in the same phase and month as plot 1. The difference was seen in plot 2 the value of the irrigation water requirement was greater. The greater need for water is caused by the fact that plot 2 is wider than plot 1. The larger area requires more irrigation water [25].

The greater need for water in plot 2 is not matched by the availability of sufficient water. Conversely, the availability of water is less than plot 1. The small efficiency in plot 1 causes less water to reach plot 2. Overall, during the first planting period of plot 2 there was a water deficit.

Table 10. Irrigation Water Balance Planting period I (paddy) plots 1 and 2

Month	Decade	Phase	Plot 1			Plot 2		
			DR	Q	Water balance	DR	Q	Water balance
			liter/second			liter/second		
September	2	Nurs	6.87	49.28	Surplus	20.13	23.07	Surplus
September	3	LPr	127.42	47.23	Deficit	373.22	22.11	Deficit
October	1	LPr	282.59	47.23	Deficit	827.73	22.11	Deficit
October	2	Init	64.24	47.23	Deficit	188.16	22.11	Deficit
October	3	Deve	67.41	47.23	Deficit	197.45	22.11	Deficit
November	1	Deve	3.17	47.23	Surplus	9.29	22.11	Surplus

November	2	Deve	0.00	58.37	Surplus	0	27.32	Surplus
November	3	Mid	0.00	58.37	Surplus	0	27.32	Surplus
December	1	Mid	0.00	63.49	Surplus	0	29.72	Surplus
December	2	Mid	0.00	63.49	Surplus	0	29.72	Surplus
December	3	Mid	0.00	69.12	Surplus	0	32.35	Surplus
January	1	Late	0.00	66.43	Surplus	0	31.09	Surplus
January	2	Late	0.00	69.12	Surplus	0	32.35	Surplus
January	3	Late	0.00	69.12	Surplus	0	32.35	Surplus
February	1	Late	0.00	69.12	Surplus	0	32.35	Surplus
Amount			551.70	872.06	Surplus	1615.98	408.17	Deficit

Calculation of the irrigation water balance during planting period II of paddy plots 1 and 2 is in Table 11. During planting period II plot 1 there was a deficit only once, namely in the LPr phase in February decade 1. The water deficit occurs because the LPr phase requires a lot of water, which cannot be fulfilled by effective rainfall and the availability of irrigation water. The deficit occurred only once due to large effective rainfall above 100 mm from January to April. Large effective rainfall is able to meet the need for irrigation water, so that the need for irrigation water is little or even zero. From May to June the effective rainfall has decreased to <50 mm, which causes the need for irrigation water to increase. The increased need for irrigation water is still fulfilled by the availability of water in irrigation canals. Overall, during the second planting period of paddy plot 1, there was a surplus or excess of water in the water balance.

During the planting period II plot 2 of the Nurs phase in January of the 2nd decade and the Init phase of February in the 2nd decade to the Mid-April phase of the 2nd decade, there was a surplus. Large effective rainfall can meet the needs of irrigation water, so there is no need for water from irrigation canals. In January 3rd decade to February 1st decade of the LPr phase, there is a deficit. In this phase the effective rainfall and the availability of channel water cannot be met. The water deficit occurred again in April in the 3rd decade of the Mid-phase to June in the 1st decade of the late phase or harvest. From April to June, the effective rainfall begins to decrease, so that the need for water increases with water availability that has not been fulfilled. During planting II plot 2 there was a deficit.

Table 11. Irrigation Water Balance during planting II (paddy) plots 1 and 2

Month	Decade	Phase	Plot 1			Plot 2		
			DR	Q	Water balance	DR	Q	Water balance
			liter/second			liter/second		
January	2	Nurs	0.00	69.12	Surplus	0.00	32.35	Surplus
January	3	LPr	65.29	69.12	Surplus	191.25	32.35	Deficit

February	1	LPr	208.84	69.12	Deficit	611.70	32.35	Deficit
February	2	Init	0.00	69.12	Surplus	0.00	32.35	Surplus
February	3	Init	0.00	74.75	Surplus	0.00	34.99	Surplus
March	1	Deve	0.00	73.34	Surplus	0.00	34.33	Surplus
March	2	Deve	0.00	73.34	Surplus	0.00	34.33	Surplus
March	3	Deve	0.00	67.71	Surplus	0.00	31.69	Surplus
April	1	Mid	1.45	67.71	Surplus	4.26	31.69	Surplus
April	2	Mid	9.12	67.71	Surplus	26.71	31.69	Surplus
April	3	Mid	19.56	67.71	Surplus	57.30	31.69	Deficit
May	1	Mid	32.12	67.71	Surplus	94.08	31.69	Deficit
May	2	Late	42.16	67.71	Surplus	123.50	31.69	Deficit
May	3	Late	45.60	62.08	Surplus	133.57	29.06	Deficit
June	1	Late	38.99	62.08	Surplus	114.21	29.06	Deficit
Amount			463.14	1028.35	Surplus	1356.58	481.32	Deficit

Maize palawija crops are planned for planting period III. Planting was carried out in June of the 2nd decade. The harvest period occurred in October of the 2nd decade. Corn did not have the Nurs and land preparation phases or LPr. Calculation of irrigation water balance during planting III plots 1 and 2 in Table 12.

Overall, the condition of the water balance during planting period III, plot 1 experienced excess water or a surplus. Water surplus occurs in the Init and Deve phases from June 2nd decade to July 3rd decade. Water deficit occurs in the Mid-August phase of the 1st decade to the Late phase of September 2nd decade. However, the difference between demand and water availability is not too far, around 10-20 liters/second. In the next Late phase, from September in the 3rd decade to October in the 2nd decade, the water demand decreases, which can be met by water from irrigation canals. Planting period III of corn crops in plot 2 there was a shortage of water or a deficit. In almost all phases there is a deficit, except for the last Late phase or the harvest season on October 2nd decade. Water shortages occur due to the large land area, low effective rainfall, and limited water availability in the canals.

Table 12. Irrigation Water Balance planting period III (palawija) plots 1 and 2

Month	Decade	Phase	Plot 1			Plot 2		
			DR (liter/second)	Q	Water balance	DR (liter/second)	Q	Water balance
June	2	Init	11.10	58.37	Surplus	32.52	27.32	Deficit
June	3	Init	12.03	56.96	Surplus	35.23	26.66	Deficit
July	1	Deve	19.17	56.96	Surplus	56.14	26.66	Deficit
July	2	Deve	30.53	56.96	Surplus	89.43	26.66	Deficit

July	3	Deve	48.11	56.96	Surplus	140.92	26.66	Deficit
August	1	Mid	55.65	52.86	Deficit	162.99	24.74	Deficit
August	2	Mid	58.55	50.56	Deficit	171.51	23.66	Deficit
August	3	Mid	67.01	50.56	Deficit	196.29	23.66	Deficit
September	1	Mid	63.31	50.56	Deficit	185.45	23.66	Deficit
September	2	Late	61.46	49.28	Deficit	180.03	23.07	Deficit
September	3	Late	47.05	47.23	Surplus	137.83	22.11	Deficit
October	1	Late	31.85	47.23	Surplus	93.30	22.11	Deficit
October	2	Late	6.61	47.23	Surplus	19.36	22.11	Surplus
Amount			512.45	681.73	Surplus	1500.99	319.08	Deficit

3.4 Cropping Pattern Optimisation

The objective (Z) of optimizing cropping patterns is to increase the planting index (PI) by maximizing the demand for irrigation water (D) against the availability of irrigation water (Q). The need for irrigation water is maximized if there is still excess water or a surplus. If there is a shortage of water or a deficit, then the use of irrigation water will be reduced, so that the existing water supply can be sufficient.

Availability of irrigation water is maximized with two alternatives. The first alternative is when there is a surplus of water, increase the planting area, and change the cropping pattern (X) by planting plants that require more water, such as paddy instead of corn crops. The second alternative is that the need for irrigation water is met by changing cropping patterns to replace plants that do not require a lot of water, such as corn crops, and reducing the planting area. Optimization of cropping patterns has limitations. The results of cropping pattern optimization calculations are not spatial, so the location of the cropping pattern cannot be determined in detail. Calculation of optimization of plot 1 cropping pattern in Table 13.

Table 13. Cropping pattern optimization plot 1

Existing							
Cropping pattern	L Op	L Ext	Q	DR	DR Total	Difference	Water balance
	Ha		lt/s	lt/s/ha	liter/second		
Paddy I	11.42	11.42	58.14	3.22	36.78	21.36	Surplus
Paddy II	11.42	11.42	68.56	2.70	30.88	37.68	Surplus
Maize III	11.42	11.42	52.44	3.45	39.42	13.02	Surplus
Amount	34.26	34.26	**179.14**	-	**107.08**	**72.06**	Surplus
Optimization							
Paddy I	11.42	11.42	58.14	3.22	36.78	21.36	Surplus

Paddy II	11.42	11.42	68.56	2.70	30.88	37.68	Surplus
Paddy III	6.28	11.42	55.09	5.95	37.34	**17.75**	Surplus
Maize III	5.14		**17.75**	3.45	17.74	0.01	Sufficient
Amount	34.26	34.26	**181.79**	-	**122.74**	**59.05**	Surplus

Irrigation water balance existing conditions during the planting periods I, II, and III, plot 1 experienced excess water or a surplus. The availability of water that is still available is optimized so that it can be utilized optimally. Optimization results show that during planting season III, the paddy cropping pattern cannot be planned as a whole, but with a portion of the land area to be planted with corn crops. This is because if the entire land is planted with paddy, there will be a water deficit. If only paddy are planned to maximize water demand, the land area will not reach the maximum. Therefore, the optimization results suggest that during planting period III plot 1, 2 cropping patterns are carried out, namely part of the land is for paddy, and the other part is for maize crops. The mechanism for utilizing irrigation water in optimizing planting period III plot 1 is that the remaining water used by paddy will be utilized by maize crops, so that the availability of water can be utilized optimally or sufficiently.

Planting period I and II plot 1 the availability of water and land has been optimally utilized. The paddy cropping pattern is planned for planting periods I and II because rainfall is effective, and the availability of irrigation water is still sufficient. Paddy requires more water than crops [9]. Increasing the paddy planting area to maximize water availability cannot be done because the land has reached the maximum area. Optimization of the plot 1 cropping pattern resulted in a Paddy-Paddy-Paddy Palawija cropping pattern.

Research conducted by [7] also showed almost similar findings. These results show that in planting periods I and II, paddy can generally be planted, while in planting period III most crops are planted with corn. Of course, this is influenced by weather and climate characteristics which influence water availability in a particular area. These similar findings are caused by the research locations which were both carried out on the island of Java.

Calculation of the optimization recapitulation of plot 1 cropping pattern in table 14. Availability of land has been utilized to the maximum both in existing conditions and after optimization. The percentage of utilization of water availability increases after optimization. The percentage of utilization of water availability in the existing conditions is 59.77%, while after optimization it increases by 67.52%. The low efficiency in plot 1 is only 64% causing inefficient use of water for irrigation.

The optimization recapitulation of plot 1 cropping pattern shows the amount of water availability is different. This is because the existing cropping pattern is in the form of corn crops, while when it was optimized it became paddy and crops. In the paddy cropping pattern there is an additional 3 decades for the Nurs and LPr phases, so that water availability increases.

Table 14. Recapitulation of Plot 1 Planting Pattern Optimization

Variable	Existing	Optimization	Unit
Land availability (**Xt**)	34.26	34.26	ha
Total land used (**X**)	34.26	34.26	
Remaining land area	0	0	
Land used	100	100	%
Total water availability (**Qt**)	179.14	181.79	lt/second
Total water demand (**Z**)	107.08	122.74	
Remaining water availability	72.06	59.05	
Water utilization (%)	59.77	67.52	%

Irrigation water balance existing condition during planting periods I, II, and III plot 2 experienced water shortage or deficit. The need for irrigation water is reduced to meet the availability of irrigation water. The alternative used is to change the cropping pattern and reduce the planting area. Calculation of optimization of plot 2 cropping patterns in Table 15.

Plot 2 of the optimization results showed a suitable cropping pattern, namely Paddy Palawija-Palawija-Palawija. The planting period of I plot 2 is still possible for the planned paddy cropping pattern with some crops. The cropping pattern plan is carried out to minimize the need for irrigation water. However, the paddy planting area is only 3.69 ha, and crops are 29.76 ha. This was done because if only the paddy cropping pattern was planned, the planting area would only be 8.45 ha of the available land of 33.45 ha. The mechanism for utilizing irrigation water in the optimization of MT I plot 2 is that the remaining water used by paddy plants will be utilized by maize crops, so that the availability of water can be utilized optimally or sufficiently. In addition, the availability of land area can be utilized optimally.

Planting period II plot 2 optimization results are planned cropping pattern. The paddy cropping pattern plan as in the existing conditions is not recommended. This is done to minimize the need for water so that the availability of water can be sufficient, as well as to maximize the planting area to the availability of land. Availability of water during planting II plot 2 can serve a palawija planting area of 19.68 ha. The existing condition of the paddy planting pattern rather than paddy can only be served by an area of 11.87 ha. Therefore, the results of the optimization suggest a cropping pattern plan for crops in the second planting period of plot 2. The planting area cannot reach the maximum available land area of 33.45 ha due to limited water availability. Planting period III in plot 2 is planned with a fixed cropping pattern of crops like the existing conditions. The limited availability of water causes the only 7.11 ha of palawija planting area that can be served.

Table15. Cropping pattern optimization plot 2

Cropping pattern	L Op	L Ext	Q	Qd	Qd Total	Difference	Water balance
	Ha		lt/s	lt/s/ha	lt/second		
Existing							
Paddy I	8.45	33.45	27.21	3.22	27.21	0	Sufficient
Paddy II	11.87	33.45	32.09	2.70	32.09	0	Sufficient
Maize III	7.11	33.45	24.54	3.45	24.54	0	Sufficient
Total	27.43	100.35	**83.84**		**83.84**	**0**	Sufficient
Optimization							
Paddy I	3.69	33.45	27.21	3.22	11.88	**15.33**	Surplus
Maize I	29.76		**15.33**	0.51	15.31	0.01	Sufficient
Maize II	19.68	33.45	31.66	1.61	31.66	0.00	Sufficient
Maize III	7.11	33.45	24.54	3.45	24.54	0.00	Sufficient
Total	60.24	100.35	**83.42**		**83.40**	**0.01**	Sufficient

Table 16. Recapitulation of Plot 2 Planting Pattern Optimization

Variable	**Existing**	**Optimization**	**Unit**
Land availability (**Xt**)	100.35	100.35	Ha
Total land used (**X**)	27.43	60.24	
Remaining land area	72.92	40.11	
Land used	27.33	60.03	**%**
Total water availability (**Qt**)	83.84	83.42	lt/second
Total water demand (**Z**)	83.84	83.40	
Remaining water availability	0	0.01	
Water utilization (%)	100	99.98	%

Land use after optimization increased from only 27.33% to 60.03%. Availability of water both before and after optimization has been utilized optimally (100%). Calculation of the optimization recapitulation of plot 2 cropping patterns in Table 16. The difference before and after optimization is the maximum utilization of available land. Availability of land cannot be fully utilized due to limited irrigation water. The availability of irrigation water is only able to maximally serve the planting area of 60.03% of the available land.

4 Conclusion

The existing irrigation water balance varies across each planting season and plot. Planting period I, II, III plot 1 there is excess water or surplus, while plot 2 occurs shortage of water deficit. Such differences occur due to the area of plot 2 service land larger than plot 1, so greater demand for irrigation water. Need of greater irrigation water is not offset with sufficient water availability.

The optimization of the planting pattern for each plot is different. The optimizing cropping pattern in plot 1 is Paddy-Paddy-Paddy Palawija. Utilization of land availability in plot 1 both in existing conditions and after optimization reaches a maximum or 100% can be utilized, while the availability of irrigation water utilization increases from 59.77% to 67.52%. The optimal cropping pattern for plot 2 is Paddy Palawija – Palawija - Palawija. Utilization of land availability increased from only 27.33% to 60.03%, while water availability both in the existing conditions and after optimization can be utilized to the maximum or 100%.

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