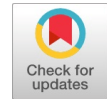


Irrigation Water Use Services Model Based on the Water Optimization



Hanugerah Purwadi, Lily Montarcih Limantara, Ery Suhartanto, Rispiningtati

Abstract: Various efforts to improve the welfare of the community have become the priority of government programs currently, especially in providing food by encouraging the development of the irrigation sector. The decline in water resources both in terms of quantity and quality also make a triggers the problem of water distribution when there is an imbalance between demand and supply. The desire among farmers to obtain water immediately may cause problems in how to distribute water fairly and equally. Sempor Irrigation System (5.888 ha) also deal with water distribution problems especially during the dry season. The purpose of this research is to determine the water distribution system based on water optimization therefore the irrigation performance can be measured more precisely. Meanwhile, the methodology is uses descriptive research method on fields' irrigation research. The results of this study will be obtained a irrigation water use services model.

Keywords: irrigation system, water optimization, water use services

I. INTRODUCTION

Water and land are the urgent factors for sustainable agricultural development of a nation [1][2][3] like Indonesia that is as agricultural country. However, water availability is sometimes deficit or surplus [4] for some agricultural area. The surplus water can be used for maximizing the agricultural yield productivity so it will produce the maximum benefit. One of the methods that can be used is the optimization technique [5]. Generally, the model of optimization is a process of the best alternative option among an amount of available solution alternatives [6][7].

Indonesia is one of the largest agricultural countries in the world with a population reaching more than 200 billion in 2019 [8].

Various efforts to improve the welfare of the community have become the priority of government programs, especially in providing food by encouraging the development of the irrigation sector as well as in urban areas and rural areas. Optimal management of available surface and subsurface water sources, related to quantity and quality, is highly needed given the increasing demands, limited resources and influenced by soil salinity [9].

The impact of changes in hydrological behaviour and changes in the physiography (land use) of the land causes the changes in the pattern of water availability that is physically felt with the emergence of floods and drought that is increasingly extreme. The decline in water resources both in terms of quantity and quality also adds to the problem when there is an imbalance between demand and supply. Water scarcity is no longer just a national issue, but later in the twenty-first century will become a major global issue [10]. This tendency also affects the pattern of irrigation water availability so that more detailed management and research is needed so that the available water can be utilized optimally so that the water needs in irrigated land can be fulfilled in accordance with predetermined planting patterns.

The phenomenon of land conversion, especially in Java (as a national rice barn) is quite alarming for the sustainability of meeting food needs both on a local scale to meet the needs of these areas and on a national scale as the main buffer for national-level food needs. The affected areas are mostly productive irrigation land including technical irrigation areas, semi-technical irrigation areas and simple irrigation areas. The timeless paddy field program becomes less effective when irrigated paddy fields are occupied by a variety of interests.

To anticipate this problem the government has established a policy on irrigated land development, which is expected to increase land and water security so that the index of cropping and land productivity can increase. Empirically, agricultural lands that are most vulnerable to land conversion are irrigated rice fields. Conversion of paddy fields to non-paddy fields in Java is 4.2% per year or \pm 148 thousand ha / year and this is precisely the case in many centres of food production centres [11].

In an irrigation system the problem regarding the pattern of water distribution becomes very important when the available debit is smaller than the debit needed in the framework of meeting water needs, especially during the dry season. The impact of the imbalance causes the yield to be less than the planned target. The yield of paddy fields (harvest) is influenced not only by the large number of levels of meeting water needs, but also by the way water is provided [12][13].

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Therefore, the use of water needs to be regulated and managed with the principle of justice so that its distribution meets the principles of on time, space, quantity and quality.

According to Hansen *et.al.* [14], how to provide irrigation water in rice fields can be done in 5 (five) ways, namely: (1) flooding; (2) by flowing through large or small furrows; (3) by utilizing subsurface water through sub irrigation; (4) by sprinkling; and (5) through a trickle system. Of the five ways in general for rice plants carried out by flooding or using a furrows system by utilizing irrigation networks that had been planned since the beginning of development. The pattern of irrigation water supply can be done by flowing continuously (stagnant constant head) or by intermittent (intermittent flow). The selection of the water delivery pattern adjusts to the conditions of the availability of existing water sources.

The known water distribution system is carried out with a group: Director General of Irrigation Department of Public Works-KP 01 [15] states that the system of water distribution by group or technical rotation serves to reduce the time of peak irrigation water needs. The advantage of this system is that it guarantees even distribution of water obtained in irrigated lands in one planting season, but this system also provides more complex implementation consequences, namely: (1) exploitation becomes more complicated and requires patience from the user; (2) the time period for giving water to the first and second plants is longer, so that the time is shorter for the second crop; (3) the percentage of water loss due to exploitation is slightly higher; and (4) the potential for social conflict among water users is

higher between locations close to those far from the point of collection.

Various efforts have been made to increase agricultural production and reduce crop failures, such as intensification of agriculture, selection of appropriate technologies, planning of new irrigation networks, and improving irrigation water management by improving the efficiency of their use. Many technical and non-technical factors have not yet been completely identified and solutions have been found. One of the problems that often occurs in the field is the loss of water in the irrigation system, both in large-scale irrigation areas (> 1,000 ha) and small-scale (<1,000 ha), water losses occur due to percolation and surface runoff [14][16][17].

II. MATERIALS AND METHODS

A. Location of Study

The location of study is conducted in Sempor Irrigation System which located at southern java in Kebumen Regency. The system utilizes the availability of water from Sempor Reservoir through Bojong Weir as a regulator weir. According to existing operational procedures, the Sempor Irrigation System also obtained the water supplies from other weirs such as the Rowokawuk Weir, Watubarut Weir and Sindut Weir. The total services area in Sempor Irrigation System reaches 5,888 ha. The map of Sempor Irrigation locations and schemes is presented in the following Fig. 1.

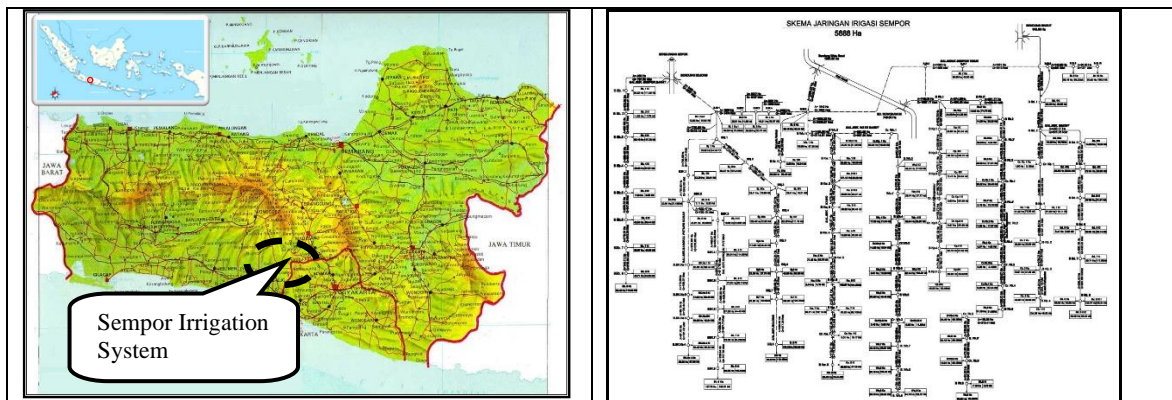


Fig. 1. The map of Sempor Irrigation location and Schemes

Source : BBWS SO Office

B. The Method of Analysis

The method of analysis this study utilises a linear programming with the purpose of getting the most optimum value between the water requirement and water availability. The principle of water supply and demand model is comparing two variables as the water is required for farming and the ability to provide water to stakeholders. The output of this method is to obtain a number from the calculation result of the ratio between the volume of water requirements for plants in an irrigation area and the volume of water that can be provided by an irrigation network.

C. Water Requirement or Demand

C.1. Water Demand for Paddy Field

The amount of water needed by the plant in a paddy field terrace is represented in this equation as follow:

$$NFR = ETc + P + WLR - Re \quad (1)$$

where

NFR = water demand in the farm (mm/day),

ETc = water demand of plantation (mm/day),

WLR = water layer replacement (mm/day),

P = percolation (mm/day),

Re = effective rainfall

C.2. Crop Water Demand

Crop water demand is the amount of water needed to replace the loss of water as a result of evapotranspiration. The amount of water plant demand (consumptive use) is counted based on this formula:

$$ETc = Kc. ET0 \quad (2)$$

Where:

ETc = plant evapotranspiration (mm/day),
 ETo = plant reference evapotranspiration (mm/day),
 Kc = plant coefficient

Water demand during land preparation is calculated by V.D Goor-Zijlstra formula, as follow:

$$IR = M \cdot e^k / (e^k - 1) \quad (3)$$

Where :

IR = irrigation water demand (mm/day),
 $M = EO + P = (1,1 ETo + P)$ (mm/day), water demand to replace the loss of the result
 $k = MT/S$
 T = the duration of land preparation (day),
 S = the water needed for saturation is added by 50 mm

D. Water Availability

D.1. Dependable Flow (Q 80%)

Dependable flow is the amount of available discharge to occupy water needs by calculates the risk of failure which possible occurs. To evaluate the dependable flow discharge is used a flow characteristic method with a dependable graph. From the graph, 80% of the discharge values are calculated for in each weir by considering the ability of the supply-discharge from the Sempor Channel. Therefore it can be known what the discharge capacity is supplied in each irrigation area. In determining the calculation of the dependable flow with an 80% probability, the Weibull Method is used, the equation can be seen as follow

$$P = \frac{m}{n+1} \cdot 100\% \quad (4)$$

Where:

P = probability (%)
 m = data sequence number
 n = amount of data

D.2. Effective Rainfall

The height of rainfall (mm) is used to determine the time of starting the first planting and to estimate the irrigation water needs in the field and to calculate the amount of effective rainfall. It is usually used the monthly rainfall data. Therefore, the effective rainfall constant / coefficient are calculated from the formula as below:

(1). The equation of daily effective rainfall for paddy plantation:

$$Padi = \text{coefficient of effective rainfall} \cdot \frac{R_{80}}{15} \quad (5)$$

(2). The equation of daily effective rainfall for palawija (soybean) :

$$Palawija = \text{coefficient of effective rainfall} \cdot \frac{R_{50}}{15} \quad (6)$$

D.3. K-Factor

The K-factor is a comparison between water requirements and water availability. The guidelines for determining parameters refer to the Criteria for Public Works Plans (KP-01). Analysis of calculations using the data such as rainfall, climatology (wind velocity, temperature, air humidity), water discharge availability, reports on plant conditions, and crop production.

$$K = \frac{Qt}{Qb} \quad (7)$$

Where:

Qt = available outflow debit

Qb = outflow debit needed

E. Water Optimization

Optimization model is the preparation of a system that accordance with the real situation, which ater could be converted into a mathematical model by separating the main elements furthermore a solution in accordance with the goals or objectives of decision can be achieved [18]

The mathematical model used to describe a linear programming problem using the following equation [19]:

Purpose Function:

$$Z = C1X1 + C2X2 + C3X3 + \dots + CnXn \quad (8)$$

Constraint Function:

$$1) a11X1 + a12X2 + a13X3 + \dots + a1nXn < b1 \quad (9)$$

$$2) a21X1 + a22X2 + a23X3 + \dots + a2nXn < b2 \quad (10)$$

$$m) am1X1 + am2X2 + am3X3 + \dots + amnXn < bm \quad (11)$$

and

$$X1 \geq 0, X2 \geq 0, \dots, Xn \geq 0 \quad (12)$$

III. RESULTS AND DISCUSSION

A. Hydrology Data

Analysis result of data has obtained 10 years of influential daily rainfall data in the Sempor irrigation area. These data are summarized into monthly data which required obtaining effective rainfall for use in hydrological calculations. The rainfall data was obtained from 6 rain gauge stations that spreading in Sempor Catchment Area such as: Karanganyar Rainfall Station, Adimulyo Rainfall Station, Rowokawuk Rainfall Station, Gombong Rainfall Station, Kuwarasan Rainfall Station and Sempor Rainfall Station, as presented in Fig. 2 as below. From the figure 2 indicates that rainfall began to fall spread throughout Sempor Irrigation Area evenly at the beginning of October to reach its peak from January to May.

The pattern of rainfall can be divided into 2 categories based on season, during the wet season the intensity of the rain is relatively constant above 130 mm / month, meanwhile in the certain month can reach up to 300mm / month. While in the dry season is below to approximately 10 mm / month but on July to August no rain occur in this area

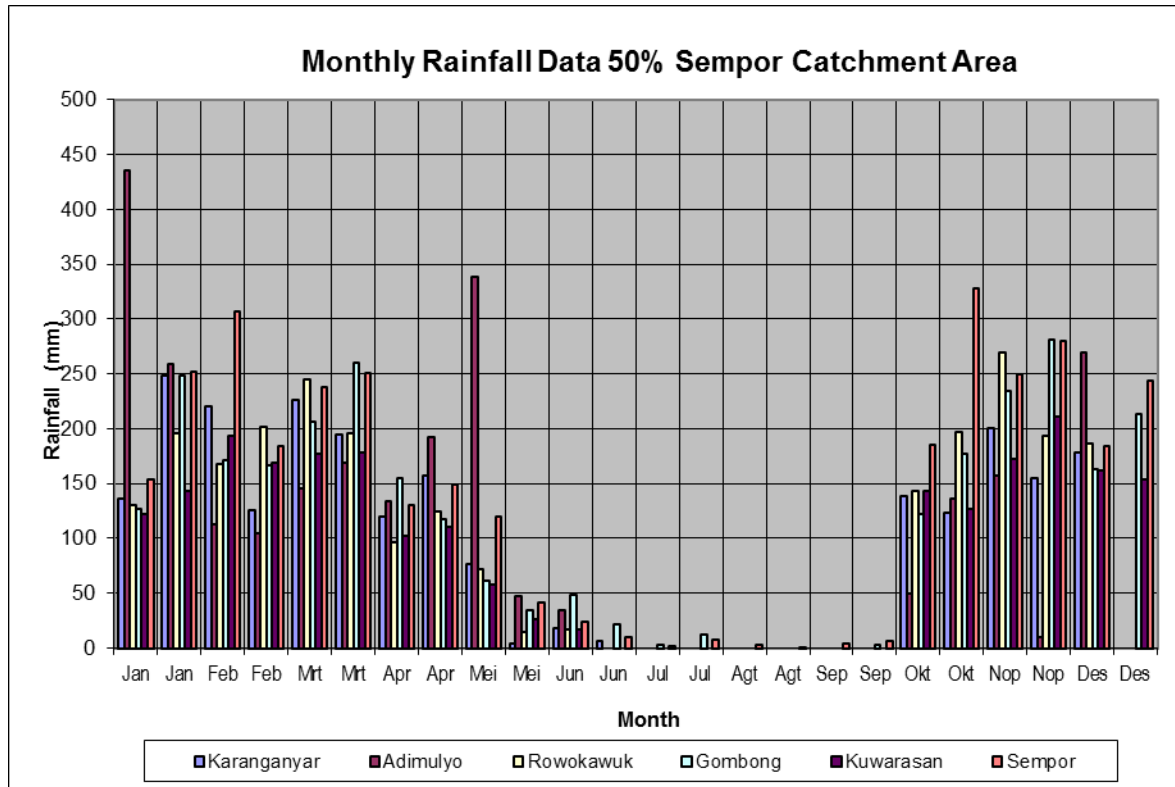


Fig. 2. Monthly Rainfall of Sempor Catchment Area
Source: Analysis Result

Even though the results of the rainfall data analysis show that in the month of October rain began to fall evenly, it has not been able to produce a sufficient river discharge to pioneer all irrigation land in Sempor. In Fig. 3 illustrates the half-monthly average discharge recorded at Bojong weir,

Watubarut weir, Rowokawuk weir and Sindut weir. The graph shows that the discharge on the river began in mid-October. This happens because more rainwater that falls to the earth is infiltrated into the ground rather than becoming a surface flow.

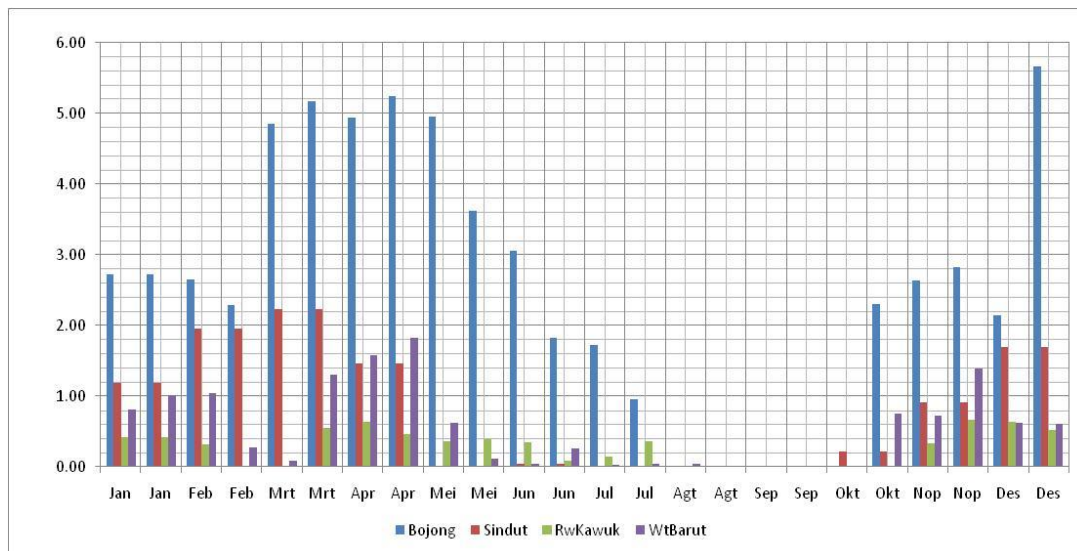


Fig. 3. River Discharge of Sempor Catchment Area
Source: Analysis Result

B. Water Availability and Water Requirement Condition

In order to fulfil the water needs in irrigation area especially during the dry season, the guidelines for operating patterns are needed. Water supply from the Sempor reservoir used to irrigate the Sempor Irrigation Area is needed when the weirs suffer from water shortages. There are two categories of water shortage problems in Sempor Irrigation Area, such as: 1) real conditions where no water is available

at the weir and 2) water is available in the field but is not sufficient to meet crop water needs according to water demand calculations. Therefore in the analysis of water optimization is calculated based on the conditions of growing season.



B.1. Existing Condition

In accordance with existing conditions in the Sempor Irrigation Area there is water deficit in the several months, such as December, April, August and September. During those months the need for water was increased to be used for land preparation and for wetting the soil furthermore salinity was maintained. Meanwhile on the other side the availability

of water was relatively constant. The deficit condition is exacerbated by the behaviour of farmers who are not use water efficiently. Farmers are over used or wasteful in the use of water in their land consequently water wasted into the drainage channels automatically. The existing condition can see as in the Fig. 4 and Table- I.

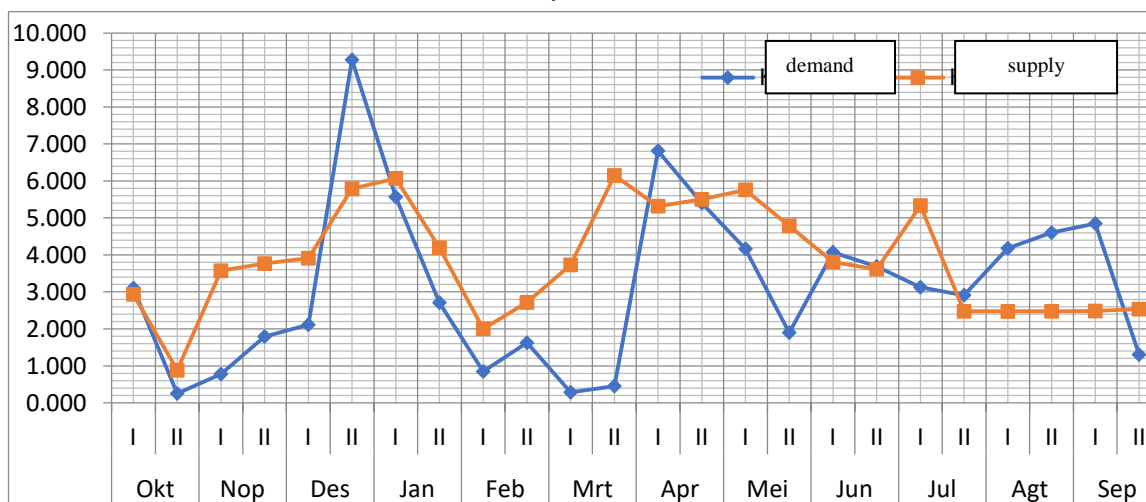


Fig. 4. Water Balance for Existing Condition
Source: Investigation Result

Table- I. Irrigation Performance Factor in the existing Sempor irrigation area

Sub Irrigation Area	Total area	Irrigated Area	Volume of Water Requirement	Volume of Water Availability	Irrigation Performance Factor
	Ha	ha	m ³	m ³	%
Bojong Irr. Area	2,599	1,223	34,836,012	16,389,065	47.05
Watubarut Irr. Area	1,627	551	21,807,692	7,386,206	33.87
Sindut Irr. Area	916	341	12,277,717	4,569,188	37.22
Rowokawuk Irr. Area	746	208	9,999,102	2,784,319	27.85
Total	5,888	2,322	78,920,523	31,128,778	36.49

B.2. Water Optimization

From the calculation of water optimization, the following results as follows: 1) The simulation using a K-factor = 0.5 (Fig. 5) shows that the irrigation performance factor is 97% (Table- II). This means that almost the farmland in the Sempor Irrigation System receives water evenly; 2) Simulations using K-factor = 0.7 (figure 6), the results of the irrigation performance factor are 75.81% (table 3). Most of the irrigate farmland area is allocated in the upstream in the sub irrigation Bojong. Meanwhile sub irrigation Watubarut obtaining water by 68.77%. It shows that the availability of

water began to decrease because it was already used in the sub irrigation above. For the smallest area of farmland which is sub irrigation rowokawuk can still be irrigated by 100%. However, in the Sindut irrigation sub-area, there was no water available therefore the irrigated land could not be utilized; and 3) Simulation using the K-factor = 1.0 (Fig. 7) obtained the results of the irrigation performance factor of 53% (Table- IV). The water is only sufficient to irrigate the smallest irrigated land, namely rowokawuk sub irrigation, while the other two sub irrigation systems do not obtain water

Irrigation Water Use Services Model Based on the Water Optimization

1. Optimization with the K-Factor Alternative (K-Factor = 0.5)

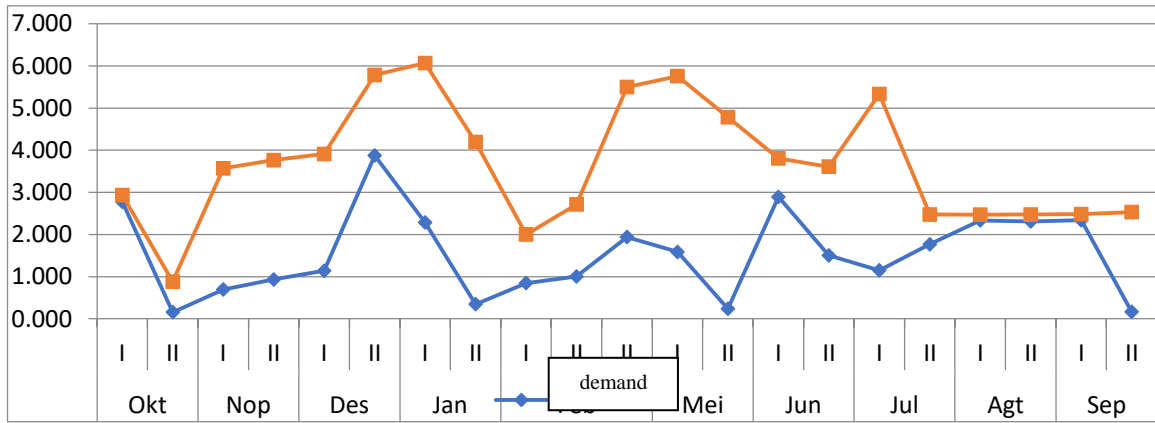


Fig. 5. Water Balance with the K-Factor Alternative (K-Factor = 0.5)
Source: Analysis Result

Table- II. Irrigation Performance Factor with the K-Factor Alternative (K-Factor = 0.5)

Sub Irrigation Area	Total area	Irrigated Area	Volume of Water Requirement	Volume of Water Availability	Irrigation Performance Factor
	Ha	ha	m ³	m ³	%
Bojong Irr. Area	2,599	2,599	20,562,428	27,792,509	100.00
Watubarut Irr. Area	1,627	1,627	12,872,285	12,525,496	97.31
Sindut Irr. Area	916	916	7,651,394	9,458,173	100.00
Rowokawuk Irr. Area	746	746	5,902,105	4,721,637	80.00
Total	5,888	5888	46,988,212	54,497,815	94.33

2. Optimization with the K-Factor Alternative (K-Factor = 0,7)

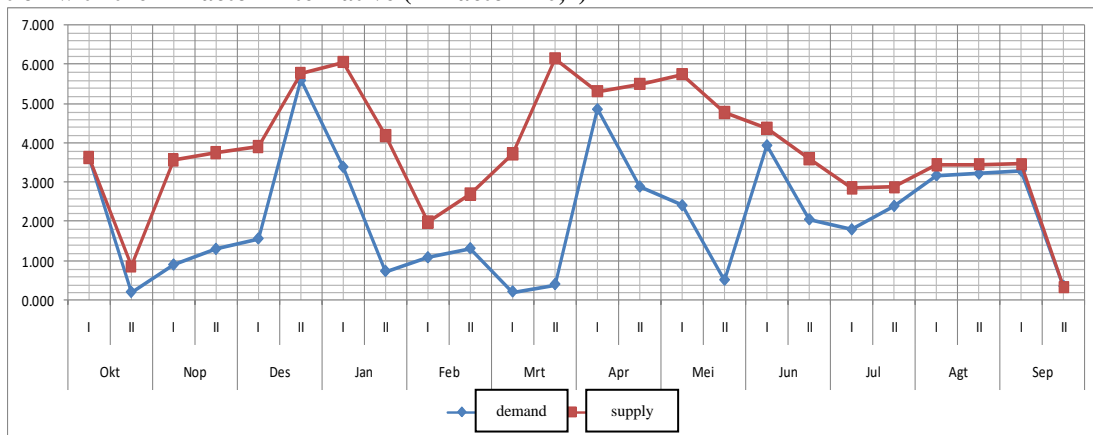


Fig. 6. Water Balance with the K-Factor Alternative (K-Factor = 0.7)
Source: Analysis Result

Table- III. Irrigation Performance Factor with the K-Factor Alternative (K-Factor = 0.7)

Sub Irrigation Area	Total area	Irrigated Area	Volume of Water Requirement	Volume of Water Availability	Irrigation Performance Factor
	Ha	ha	m ³	m ³	%
Bojong Irr. Area	2,599	2,599	26,028,389	30,581,856	100.00
Watubarut Irr. Area	1,627	1,119	11,650,280	12,404,470	68.77
Sindut Irr. Area	916	0	0	0	0.00
Rowokawuk Irr. Area	746	746	7,471,019	5,195,516	100.00
Total	5,888	4464	45,149,688	48,181,841	75.81

3. Optimization with the K-Factor Alternative (K-Factor = 1,0)

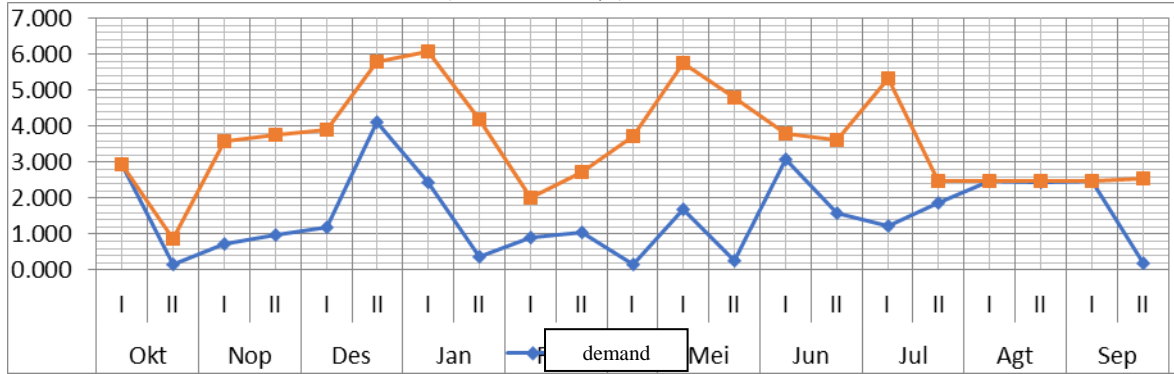


Fig. 7. Water Balance with the K-Factor Alternative (K-Factor = 0,7)

Source: Analysis Result

Table- IV. Irrigation Performance Factor with the K-Factor Alternative (K-Factor = 1.0)

Sub Irrigation Area	Total area	Irrigated Area	Volume of Water Requirement	Volume of Water Availability	Irrigation Performance Factor
	Ha	ha	m ³	m ³	%
Bojong Irr. Area	2,599	2,379	24,133,763	34,882,887	91.52
Watubarut Irr. Area	1,627	0	0	0	0.00
Sindut Irr. Area	916	0	0	0	0.00
Rowokawuk Irr. Area	746	746	7,471,019	6,123,437	100.00
Total	5,888	3125	31,604,782	41,006,324	53.07

4. CONCLUSION

During the dry season, the pattern of operations for weirs is very necessary for the purposes of water distribution in a fairly, equitable and timely. The pattern of water supply with factor-K = 0.70 and factor-K = 1.0 indicates that the volume of water is insufficient to face cropping needs and if it has been applied irrigation performance is less than 100%. While giving irrigated water more than specified can result water shortages in the following months, therefore the intensity of planting cropping cannot reach 300% in one year. Water optimization is needed if there is a decreasing water availability while the demand for water for plantations increasing or is relatively constant.

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