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Optimizing agricultural land area to increase productivity for anticipating decreasing irrigation water supply

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Abstract. In order to maintain food security in Indonesia it is very necessary to organize the provision of irrigation water as well as possible. Current surface water discharge conditions have decreased compared to 10 years ago so that there really must be efficiency and wise efforts in the provision of irrigation water in paddy fields. Many efforts to increase the productivity of paddy fields and one of them is by optimizing the area of paddy fields and regulating cropping patterns in the paddy fields. In the initial stage of this study an analysis of the availability of surface water discharge was then analyzed for irrigation water requirements that could be given to each paddy field in accordance with a predetermined cropping pattern. Then a land area simulation is carried out to obtain the most optimal land area. This simulation is carried out in the conditions of the wet season, the normal season and the dry season. Simulations are carried out with various cropping patterns including rice, secondary crops and sugar cane. Simulation results show that the most optimal land area is in the wet season, then the normal season and the dry season.

1. Introduction

Irrigation is very necessary for the survival of agricultural land to maintain and even improve food security in Indonesia [1]. Provision of irrigation water for agriculture needs to be managed in an appropriate, efficient, wise and sustainable manner so that its existence and function is increasingly maintained. Management and utilization must be carried out fairly, evenly according to the existing conditions of irrigation water discharge [2].

Planting planning on agricultural land is outlined in the planting management document called the Global Planting Plan published by the government and offices or agencies in charge of managing the distribution of irrigation water and must be obeyed by the community in carrying out farming activities in their respective plots [3]. The Global Planting Plan is prepared based on surface water conditions [4]. Considering the condition of surface water including irrigation water, which is decreasing, efforts must be made to efficiently use irrigation water while maintaining or increasing production yields [5]. Many efforts and one of them is a strategy to maximize the productivity of agricultural land that is to regulate cropping patterns that focus on the maximum land area [5].

With global warming causing climate change, the climate is uncertain and the rainy season has shifted as well as the dry season [6]. Surface water changes and the volume is also uncertain. Agriculture is one of the sectors that is affected by climate change so it must be taken seriously [7].

2. Materials and method

To analyze the need for irrigation water, of course, consideration must be given to the condition of surface water discharge throughout the year [8]. To analyze the need for irrigation water, many methods have been used including Water Balance, Relative Second Crop Factor - Relative Second Crop Area and Cropwat Method 8.0. From previous studies it has been produced that the most suitable method used in the current conditions is the Relative Second Crop Factor method - Second Crop Extensive Relative modification by adding parameters that have never been added before namely the amount of rainfall and the physical condition of the soil [2].

To start planting does not have to be the same in all regions because rainfall conditions and soil physical conditions are different.

To further maximize the results of agricultural productivity, research has been conducted to maximize the area of land with certain cropping patterns.

Before calculating the maximum irrigation water requirements and land area, first the hydrological analysis stage is carried out which includes:

2.1. Rain data consistency test

Daily, monthly and annual rainfall data are used from 2008 to 2017. The closest rain stations that affect the Molek Irrigation Area are Sumber Pucung rain station, Kepanjen rain station, Kali Pare rain station, and Pagak rain station.

2.2. Regional average rainfall analysis

The Thiessen coefficient for the Molek Irrigation Area, obtained from the Thiessen area calculation is:

Table 1. Thiessen Coefficient.

Station	Area (km2)	Thiessen Coefficient
Sumber Pucung	22.3749	0.43
Kepanjen	25.4656	0.49
Kali Pare	0.1414	0.00
Pagak	3.9850	0.08

Hydrological analysis and monthly average rainfall recapitulation are presented in Figure 1. The results of the analysis of regional average rainfall data by the Thiessen method are used to determine the value of rain falling on the Molek Irrigation Area based on the distribution of rainfall from each surrounding station that has an influence on the Molek Irrigation Area.

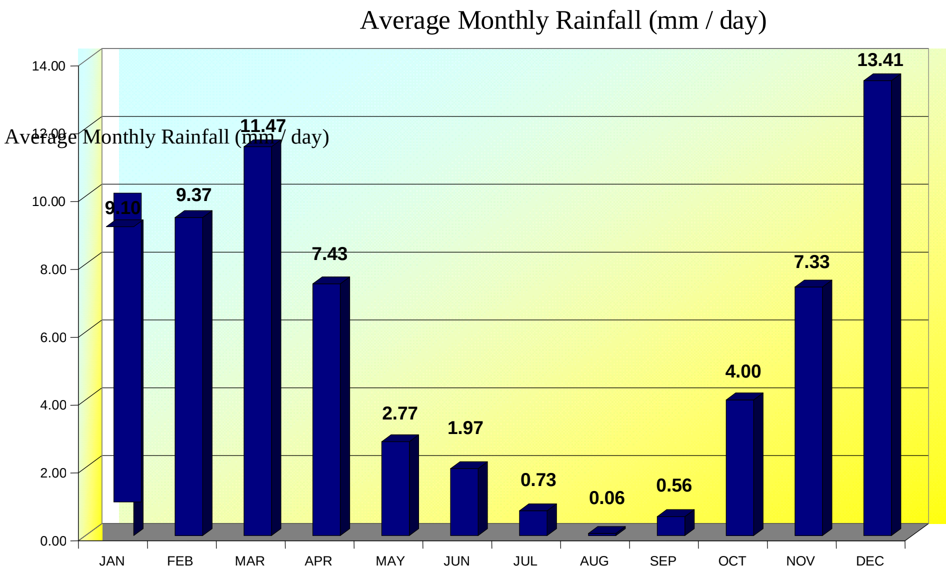

Figure 1. Monthly average rainfall of irrigation molek area (mm / day).

2.3. Analysis of irrigation intake discharge availability

Analysis of the availability of irrigation intake discharges can be done using:

- If discharge data is available, analysis of water availability can be done based on time series data from existing (historical) flowrate data.
- If discharge data is not available or data is available for less than five years, water availability analysis is carried out based on rainfall, climate and watershed data using the rainfall-runoff model.

Dependable discharge reflects a number that can be expected to occur at a control point related to time and reliability values. To determine the magnitude of the dependable discharge required a long series of discharge data that is owned by each river discharge observation station. The method that is often used for dependable discharge analysis is the statistical method (ranking).

Considering that the irrigation water in the Molek Irrigation Area is taken from the Brantas river, the calculation of the availability of irrigation water discharge also becomes one system with the Brantas river and must consider a reliable discharge. The magnitude of reliability taken for the optimum completion of water use is done first by ranking using the frequency / probability analysis with the Weibull equation:

$$P(Xm) = \frac{m}{N+1},$$ which :

Xm = a collection of values / discharge expected to occur with certain reliability

$P(Xm)$ = probability, the probability of a set of expected values / discharge during the observation period

Dependable discharge 80% (Q80) means that the probability of the discharge to be equaled or exceeded is 80%, which means that a failure is likely to occur with 100% probability reduced by 80% or 20%. It can also be interpreted that in 5 years there is a possibility of a failed year. The steps in determining the dependable discharge are:

- Sort the discharge from the largest to the smallest.
- Calculate the probabilities that occur using equations $P(Xm) = \frac{m}{N+1}$.

- Determine the discharge with an 80% probability by interpolation.

Calculation of dependable discharge in the Molek Irrigation Area uses the basic month method, ranking data sorted for each sequence of monthly discharge data so that a reliable discharge of 25% for the wet season year, 80% for the normal season year, and 90% for the dry season year, as presented in Table 2.

Table 2. Dependable discharge 25% Wet season year, 80% Normal season year, and 90% Dry season year of Intake Molek Irrigation Area (m^3/sec).

Opportunity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
80	4.80	5.97	6.47	6.47	6.42	6.15	5.85	5.04	4.89	4.54	5.69	5.69
90	3.52	3.63	5.00	3.65	3.49	3.22	3.09	2.98	2.88	2.91	4.35	3.14
25	7.26	7.38	7.43	7.38	7.40	7.46	7.42	7.37	7.16	6.99	6.71	7.35

2.4. *Dependable rainfall analysis*

Dependable rainfall is the average rainfall in the dependable for the possibility of fulfilling water than had been planned for irrigation purposes. The dependable rainfall is used to determine the effective rainfall which is the rainfall used by plants for growth. The dependable rainfall for rice plants is set at 80% while for crops is 50%.

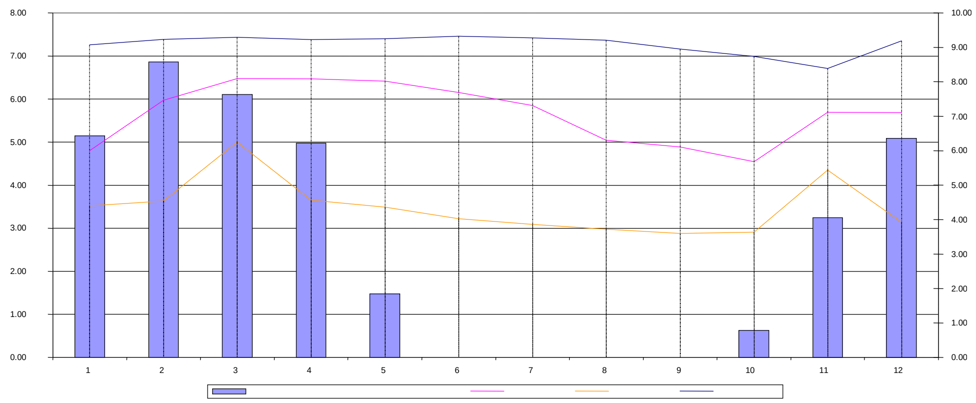

Figure 2. Dependable rainfall pattern 80% basic month method for rice plants on dependable discharge basic month method.

2.5. *Analysis of effective rainfall*

The amount of effective rainfall for plants is determined 10 daily per month. For rice planting: Re = (0,7 x R80) and for second crop: Re = R50.

which:

Re = effective rainfall (mm)
R80 = probability monthly rainfall 80 % (mm)
R50 = probability monthly rainfall 50 % (mm)

2.6. *Factors parameter for plant-irrigation water needs*

Irrigation water is the amount of water that is generally taken from rivers or reservoirs and flowed through an irrigation network system, in order to maintain the balance of the amount of water in agricultural land. The amount of water needed to meet the needs on the land that must be available and passed on the irrigation channel is calculated based on several parameters including the following: 1). Water needs for land preparation. 2). Substitution of water layers (*water level requirement*). 3). Irrigation efficiency.

From the results of laboratory analysis, it can be seen that the condition of the soil types in the Molek Irrigation Area is the dominant distribution of Alluvial species. Physically based on the results of field sampling, soil conditions in the Molek Irrigation Area have a texture of sandy loam soil with an average moisture content of 6.28%. From this physical condition, a percolation value of 4.5 mm / day was taken in this study.

2.7. Water needs for land preparation
Water requirements for land preparation generally determine the maximum irrigation water requirements. Water for land preparation is useful to prepare soil moisture for plant growth. This method is based on the need for water to replace water losses due to evaporation and percolation in paddy fields that have been saturated during the land preparation period. Important factors that determine the amount of water needed for land preparation are the length of time needed to complete land preparation and the amount of water needed for land preparation.

2.8. Substitution of water layers (Water Level Requirements).
Substitution of water layers is closely related to soil fertility. Sometime after planting, water that is flooded on the surface of the rice fields will be dirty and contain substances that are no longer needed by plants and will even damage plants. This puddle needs to be disposed of so as not to damage plants in the field. When removing the inundation layer, the garbage that is on the surface of the water will be left behind, as well as the mud carried from the canal during irrigation. Puddled water that needs to be removed needs to be replaced with new, clean water.

2.9. Irrigation efficiency
Irrigation efficiency in the Molek Irrigation Area is calculated based on water loss during the drainage process along the channel.

Calculate irrigation efficiency for January:

- Primary data loss (Kp) January = 20.82 %
- Secondary data loss (Ks) January = 21.33 %

Then the amount of irrigation efficiency for January is:

$$= \left[\left(\frac{100}{(100 + Kp)} \right) \times \left(\frac{100}{(100 + Ks)} \right) \right] \times 100$$

$$= \left[\left(\frac{100}{(100 + 20.82)} \right) \times \left(\frac{100}{(100 + 21.33)} \right) \right] \times 100$$

= 68.22 %

For the month of February to December the same formula is used and from the results of the calculation the average irrigation efficiency is taken every season, so that the irrigation efficiency obtained when the Rainy Season (MH) is 68.813%; the Dry Season 1 (MK1) of 69.057% and the Dry Season 2 (MK2) of 64.275%.

2.10. Irrigation needs calculation method
In line with the purpose of this research, what needs to be done first is to analyze the Relative Second Crop Factor method - Relative Second Crop Area which has been used by comparing the Water Balance method and the Cropwat 8.0 method. After that, analyzing the calculation of irrigation water needs using the most appropriate method and approaching the Relative Second Crop Factor Method -

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Relative Second Crop Area which has been used by adding parameters that have never been added, namely rainfall and soil physical condition.
The last is to compile a new Global Planting Plan and its development procedures based on the maximum land area.

3. Results and discussion

3.1. Irrigation water needs relative second crop factor method - relative second crop extent

To facilitate the implementation in the field, the method of calculating plant water needs that has been done is to use the Relative Second Crop Factor Method - Relative Second Crop Area. Relative Second Crop Factor Value is the debit of water needed in a tertiary tapping building by a one-hectare palawija plant.

To calculate the need for irrigation water in tertiary plots, it has been assumed that the Relative Second Crop Factor value = 0.23 lt / sec / ha. By using the Relative Second Crop Factor value, the relative Second Crop area is the product of the crop area of a type of plant with a comparative value between the crop water needs and the Second Crop water demand. This comparison value is expressed as the plant coefficient of relative Second Crop area.

Before calculating irrigation water requirements the Relative Second Crop Factor Method - Relative Second Crop Extents for rice, Second Crop, and sugar cane plants, first is a search of planting area with the stipulation that 3% of the area of one planting season is used for nurseries, and the area of cultivation = area of image x wide seed-planting-tillage.

The calculation determines in advance the total area of rice planting in each period as follows:

3.2. Rice planting season rainy season class I

Starting in December, period II with a planting area of 1291 ha with management of nursery area distribution, cultivation of land as in the following table.

Table 3. Determination of seedling area, cultivation, planting season rainy season group.

			MH												MKI
					Jan			Feb			March			Apr	
			2	3	1	2	3	1	2	3	1	2	3	1	2
Planting Season	Area (ha)	MH Group I													
		MH Group II			PL				RICE I			WLR			RICE I
		MH Group III													
MH Group1	1291	seeds	38.73												
		work	606.77	1329.7	1291	645.63									
		planting				645.5	1291	1291	1291	1291	1291	1291	1291	**1291**	645.5

3.3. Rice planting season Dry season I class I

Starting in April, period II, with a planting area of 920 ha, the management of the nursery, land cultivation and planting area distribution is as shown in Table 4.

Table 4. Determination of Seedling area, cultivation, planting of dry season I season I group.

			MKI												MKII
			Apr		May			Jun			Jul			August	
			2	3	1	2	3	1	2	3	1	2	3	1	2
Planting Season	Area (ha)	MH Group I													
		MH Group II			PL			RICE II			WLR			RICE II	
		MH Group III													
MK Group I	920.33	seeds	27.61												
		work	432.6	947.9	920.3	460.2									
		planting				460.2	920.3	920.3	920.3	920.3	920.3	920.3	920.3	920.3	460.2

3.4. Rice planting season dry season II group I

Starting in August, period II, with a planting area of 941 ha, the management of the nursery, land cultivation and planting area management is as shown in Table 5.

Table 5. Determination of Area of Seedlings, Cultivation, Planting of Dry Season II Growing Season Group.

			MKII							MH	MKII				
			Oct			**Nov**			**Dec**		**Aug**		**Sept**		
			1	2	3	1	2	3	1	2	2	3	1	2	3
Planting Season	**Area (ha)**	**MH Group I**													
		MH Group II	RICE III			WLR			RICE III		RICE II		PL		
		MH Group III													
MK II	941	seeds									28.23				
Group1		work									442.3	969.2	941	470.5	
		planting	941	941	941	941	941	941	941	470.5				470.5	941

The results of an alternative analysis of simulation of the most optimal area of paddy and area of rice crops that produce water equilibrium for availability and needs in each November planting schedule Period I, II, III, December Period I, II, III, January Period I, II, III, February Periods I, II, III, in the wet season year, are presented in Table 6 and Table 7.

Table 6. Results of Analysis of Rice Field Simulation for Wet Season Year November-December

	Wet Season Year					
	November			December		
	P I	P II	P III	P I	P II	P III
	Simulation of Rice Planting Area					
Planting	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)
Rice 1	3111.58	3137.13	3350.15	3883.00	3505.07	3543.80
Rice 2	3127.60	3616.40	3372.00	3433.10	3494.20	2761.00
Rice 3	2611.00	2400.00	2541.00	2541.00	2470.00	2569.00
Second crop 1	0.00	0.00	0.00	0.00	0.00	0.00
Second crop 2	0.00	0.00	0.00	0.00	0.00	0.00
Second crop 3	0.00	0.00	0.00	0.00	0.00	0.00
Cane	49.00	49.00	49.00	49.00	49.00	49.00
Total	8899.18	9153.53	9263.15	9906.10	9518.27	8922.80
	Simulation of Rice and Second Crop Area					
Planting	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)
Rice 1	3117.77	3137.13	3350.15	3880	3505.07	3543.8
Rice 2	2761	2761	2761	2761	2761	2761
Rice 3	2400	2216	2258	2258	2216	2188
Second crop 1	54	54	54	54	54	54
Second crop 2	1173	1173	1173	1173	1173	1173
Second crop 3	733.33	1110	1110	1110	907.18	1110
Cane	49.00	49.00	49.00	49	49	49
Total	10239.1	10451.13	10706.15	11285	10616.25	10829.8

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Table 7. Analysis results of rice field simulation for wet season year January-February.

	Wet Season Year					
	January			February		
	P I	P II	P III	P I	P II	P III
	Simulation of Rice Planting Area					
Planting	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)
Rice 1	3983.00	3983.00	3983.00	3808.72	3769.99	3300.08
Rice 2	3005.40	3066.50	3005.40	2740.55	2464.45	2588.95
Rice 3	2400.00	2400.00	2470.00	2642.00	2995.00	3385.00
Second crop1	0.00	0.00	0.00	0.00	0.00	0.00
Second crop 2	0.00	0.00	0.00	0.00	0.00	0.00
Second crop 3	0.00	0.00	0.00	0.00	0.00	0.00
Cane	49.00	49.00	49.00	49.00	49.00	49.00
Total	9437.40	9498.50	9507.40	9240.27	9278.44	9323.03
	Simulation of Rice and Second Crop Area					
Planting	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)
Rice 1	3880	3880	3880	3776.18	3659.99	3292.05
Rice 2	2622.95	2761	2664.37	2346.85	2208.8	2208.8
Rice 3	2258	2258	2336	2541	2823	2824
Second crop 1	54	54	54	54	54	54
Second crop 2	1173	989.7	1020.25	1173	928.6	1173
Second crop 3	1110	1110	1110	1110	1110	1110
Cane	49	49	49	49	49	49
Total	11146.95	11052.7	11064.62	11001.03	10784.39	10661.85

4. Conclusion

Recapitulation of rice planting area that produces the most optimal value is:

- In the wet season year will produce the largest area of production in one year if the paddy field is scheduled to be planted with rice only in December period I which is: 9906.1 ha.
- In the normal season, the largest production area will be produced in one year if the paddy field is scheduled to be planted with rice only in February, period III, which is: 7701.36 ha.
- In the dry season, the largest production area will be produced in one year if the paddy field is scheduled to be planted with rice only in February, period II, which is: 4321.33 ha.

Recapitulation of rice planting and second crop area that produces the most optimal value is:

- In the wet season year will produce the largest area of production in one year if paddy fields are scheduled to be planted with rice and secondary crops in December period I which is: 11285 ha.
- In the normal season, the largest production area will be produced in one year if the paddy field is scheduled to be planted with rice and secondary crops in February period III, which is: 9436.22 ha.
- In the dry season, the largest production area will be produced in one year if the paddy field is scheduled to be planted with rice and secondary crops in February period III, which is: 5944.87 ha.

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